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ABSTRACT

The insufficient educational backgrounds of secondary level science teachers and lack of student involvement in science were addressed by the implementation of a comprehensive science research program. A pretest was employed to measure the weaknesses of the science teachers at the target school. Learning strategies based upon pretest results were implemented to upgrade the skills of the science teachers. Workshops were developed to instruct the teachers in the area of science research. Results indicate a substantial improvement in the background knowledge of the science teachers. Student participation in science at the target school also improved. Included are the purpose, research and solution strategy, methodology, results, and recommendations. The pretest, the analysis of results, and a research handbook are appended. (Author/KR)

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# THE DEVELOPMENT AND IMPLEMENTATION OF A PROGRAM TO PROMOTE SECONDARY LEVEL SCIENCE RESEARCH EDUCATION

by
RONALD R. LEE

A Practicum Report
submitted to the Faculty of the Center for the
Advancement of Education of Nova University in
partial fulfillment of the requirements for the
degree of Master of Science.

July/1990

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## Authorship Statement

I hereby testify that this paper and the work it reports are entirely my own. Where it has been necessary to draw from the work of others, published or unpublished, I have acknowledged such work in accordance with accepted scholarly and editorial practice. I give this testimony freely, out of respect for the scholarship of other workers in the field and in the hope that my own work, presented here, will earn similar respect.

Ronald R. Lee

## Abstract

The Development and Implementation of a Program to
Promote Secondary Level Science Research Education
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University, The Center for the Advancement of Ed.
Descriptors: Secondary Education/Science Research/
Science Course Improvement Project/Science
Education/Learning Strategies in Science/Hands-On-
Science/Study and Teaching/Upgrading Science Ed./
Curriculum Innovations/Teacher Effectiveness
Training/Independent Study/Laboratory Science

The insufficient educational backgrounds of secondary level science teachers and lack of student involvement in science was addressed by the implementation of a comprehensive science research program. A pretest was employed to measure the weaknesses of the science teachers at the target school. Learning strategies based upon pretest results were implemented to upgrade the skills of the science teachers. Workshops were developed to instruct the teachers in the area of science research. Results indicated a substantial improvement in the background knowledge of the science teachers. Student participation in science at the target school also improved. It was concluded that a science research handbook for teachers was greatly needed. Appendices include the analysis of results and a research handbook.

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# Chapter I

## Purpose

This practicum was implemented in a high school located in the South Florida area. The school is situated in the southwestern portion of the district where, because of rapidly growing development, the student population is surging beyond the capacity of the facility. The school grounds occupy forty-two acres, one of the largest campuses within the district.

As compared to many other high schools in the district, and by virtue of its rather exclusive and upper middle class surroundings, the school has enjoyed a reputation among educational professionals within the district as being a very desirable place to work. The reasons for this positive reputation are many. The physical plant includes a brand new polyurethane outdoor all weather track and field facility. It is one of the best in the state and the only one of this type in South Florida and is used by five other high schools in the district. The auditorium has a state of the art public address system and a seating capacity of seven hundred and fifty students. The English department is equipped with a modern electronic language laboratory and the Math department has four fully-equipped computer labs. The media center is modern in every sense of the word. It enjoys thousands of publications and a computer-based literary search data base system that is considered to be one of the best in the district. The science wing is furnished with seven laboratories. Each is equipped with modern scientific apparatus, an Apple IIe computer, and tools necessary in teaching today's high-tech sciences.

Being surrounded by a community of rapid growth, this school has felt a surge of new support from the surrounding businesses. The involvement of businesses and local governments has been most positive for the school and for those offering support. Some of that support has been directed toward such projects as providing scholarship and job placement oportunities for the students, guest speakers for all subject areas, and access to community resources. The school's exterior landscape has been given a new look recently due to the generous cooperation of one of the areas new businesses.

Along with the growth of businesses in the community, the school has been affected by a substantial growth in student population. The current enrollment has pushed the school population to two thousand three hundred and fifty students. A breakdown of the population shows that seven-hundred of these students comprise the Freshman class making it the largest segment of the student body population. Second is the Sophomore class having five-hundred and sixty students. The Senior class is next with five-hundred fifty students, leaving the Junior class the least populated with a class member count of five-hundred and forty students. The ethnic background of the school's population is quite varied. There are three American Indians, twenty-five Asians, sixty Blacks, two-hundred and eight Hispanics, and two-thousand and fifty-four Whites.

To meet the needs of such a large student population, there are over one-hundred and fifteen full-time faculty members, who combined with other school based personnel offer over three-hundred and fifty courses. Most staff members participate in inservice workshops throughout the year and all hold a valid Florida teaching certificate making them qualified to teach. In responding to a thirteen item questionnaire recently, the staff expressed strong positive responses concerning the school and generally agreed that morale among the faculty was good.

This writer has taught Science for sixteen years within the district; the last five as a member of this school's Science Department. The writer is one of fifteen members within the department and is currently teaching grades ten through twelve. With a large student population. the Science Department is responsible for offering a total of eighteen instructional courses. Each member of the department teaches five science sections daily for a total of seventy-five classes. In the capacity of science teacher, the writer is devoted toward assisting all students in general and science students in particular in achieving their maximum potential academically, socially, and personally.

Science research and programs provide enormous benefits to both participating students and society in general. Students learn a variety of skills which they would not be taught in an ordinary classroom situation. Society benefits from having motivated, thinking young people as well as having information added to the general fund of scientific knowledge. Public relations between the school system and the community are strengthened by science projects and competition. People become more interested in what is happening in the school system and ultimately, this may mean more money, more equipment, better teachers, improved facilities, and more help from the public.

Academically, students learn procedures in research and experimental techniques. Their ability to think both creatively and scientifically is enhanced as they go through the process of selecting a topic, researching data concerning it, analyzing what others have done, rejecting and modifying various techniques, conducting experimentation, observing results, and presenting their data to others. They also, of course, learn a great deal about their subject. This type of learning is exciting.

Finally, science research and programs are of great academic value because they provide a creative and productive outlet for students who find it difficult to relate to the traditional classoom atmosphere. Many students have decided to remain in school because of their interest in science projects and have gone on to greater achievements when they could have easily joined the ranks of the non-productive.

At the target school, it has been observed that student involvement in the sciences is declining. This is evidenced, in part, by the lack of participation of the target school in the districts Annual Science Fair. For the past two years, the districts Annual Science Fair has been attended by representatives of every high school in the district, with the exception of the target school. The science department has neglected to develop a school-wide science fair which would promote interest in student involvement on the district level.

This lack of student involvement is being directly attributed to the inadequacies of the science department personnel. At the present time there is one science research class being taught at the target school. Other high schools in the district with similar enrollments have at least four. Science research methods and techniques should be implemented, to a certain degree, in all laboratory classes. They are not. Teachers are reluctant to offer science research classes for fear that their educational background in the sciences are insufficient. Teachers are unaware of the community resources that are available who are eager to assist schools within the community.

There are several associations in the form of organizations and businesses as well as government agencies that have numerous programs, activities, and resources which are helpful to students interested in the sciences and engineering. They include publications, career planning information, films, research grants, student memberships, speakers, educational visits, school guidance, a bridge-building contest, and more.

Guidance councelors have stated that once students have completed three years of science and have met the requirement for graduation, they are no longer interested in taking a science class as an elective. Students have expressed a desire to take science classes that are less structured in terms of rote memorization and test taking. The freedom of researching a topic of interest and the ability to incorporate sophisticated pieces of scientific apparatus is a request of many students. Currently, upper level science courses as taught by the teachers within the science department, do not allow the students such academic freedom.

As a means of documenting the anticipated results of this study, the researcher administered a pretest to all fifteen members of the science department within the target school. The results clearly demonstrated that the teachers needed to be informed. A science research handbook was developed as a means of instructing the teachers in the area of science research. After school in-service was held in order to disseminate the needed materials from the science research handbook. Additionally, since the target school does not hold an annual science fair, the development and implementation of the science research handbook would serve as a measurable tool in determining increased student participation, documenting the accomplishments of the target group.

Other problems addressed in this study included a lack of student enrollment in elective science courses, the offering of only one science research class, and the reluctance of the science faculty within the target group to incorporate science research techniques into all laboratory oriented courses. To further document the anticipated outcome of this study, the researcher would document, upon completion of the ten-week implementation, the following:

I. The number of students enrolling in elective science classes will increase by ten percent.

II. Science research classes will increase from one section to three sections.

III. The science department will adopt the policy of incorporating science research techniques into all laboratory oriented classes.

Finally, the science teachers within the department would demonstrate a more positive attitude toward promoting student involvment in district level science competition as evidenced by observations made by the researcher.

# Chapter II

## Research and Solution Strategy

What are the implications of the nature of science for science teaching in this day and age? Science is necessarily a dynamic, changing enterprise and thus should be presented as such in our modern science teaching. Not only will this emphasis on the dynamic nature of science give a "truer" picture of science, but hopefully it will help young people to expect changes, to have positive attitudes towards changes, and to prepare them for the future. Traditional or conventional type science courses, which present science as an immutable body of disparate facts, become outdated quickly and therefore do not provide the experiences needed for understanding and coping with change. Neither do these courses present a good picture of the scientific enterprise.

Science is a dynamic, organized body of knowledge, acquired through experimentation and observation. Science teaching, therefore, should reflect the processes and methods of modern science. It should be emphasized in our teaching, that there is no single method and no formalized set of procedures which lead to discovery. Although there are general procedures such as questioning, observing, hypothesizing, collecting and interpreting data, which are common to all the sciences, the specific processes and procedures used vary from one branch of science to another. Whatever the science taught, the general and specific science processes and methods of inquiry should be emphasized.

A recent study conducted by Bracey (1988), found that science teachers on the secondary level devote little time in promoting the skills necessary for scientific experimentation. The researchers in the study observed eleven tenth-grade teachers as they presented two topics in life science. The researchers found that the teachers spent from eighty-nine to one hundred percent of the time on presenting content, with little or no time spent inculcating positive attitudes toward science or discussing the social impact of science, scientific reasoning, or experimentation that led to the discovery of the material they were presenting in their lessons. The results of the research were reported in the Winter 1987 issue of the American Educational Research Journal. Bracey's findings pointed to a lack of scientific background on the part of the teachers as a reason why they did not deviate from the subject content.

In a report published by Cavazos (1989), he discussed a recent address before the Council of Scientific Society Presidents in Washington D.C., presented by the U.S. secretary of education. The address discussed American students' inadequate performance in math and science. The secretary of education cited five causes for the problem. The problems included insufficient time devoted to science in schools, a mathematics curriculum that needs revision, low-quality instruction, unprepared teachers, and textbooks that present unrealistic word problems. Calling for the redressing of these problems, he stated that alternative routes to hiring teachers should be explored, extra help for students should be ensured, and partnerships between schools and business should be expanded.

In a comprehensive study Brinckerhoff (1989) stated that teacher resource centers are effective for addressing the needs of science teachers to update information in their field. He discussed how these needs could be met if school systems were equipped to provide information of all sorts for classroom use, to handle apparatus, to provide instruction, and to serve as a clearinghouse. He stated that the success of a science curriculum depends on the existence of a resource center that concentrates on providing teacher inservice workshops to update teachers' skills.

In a study by Sweet (1988), he explained how the District of Columbia school system recently coordinated a successful volunteer project involving the placement of volunteer scientists in public schools to help teach science and mathematics. The program, the Science/Math Education Project, was initiated by Theodore D. Drury while he was doing public affairs work for the National Science Foundation. Drury found a number of volunteers from a list of retired military officers which was provided by the Reserve Officers Association. An evaluation of the program concluded that it was viewed as successful by teachers and principals and that students enjoyed working with volunteers and performed well with them. Science teachers involved with the project were especially positive in their evaluation, citing an increase in faculty morale as a result of the program.

The role of the National Science Foundation (NSF) in the development of precollege science courses has been decisive but controversial. In 1959, when NSF began funding high school science curriculum development, projects were directed primarily by scientists. By 1963, teachers had become the promoters of new programs whose implementation became increasingly institutionlized. The National Academy of Sciences and

Engineering seems to have linked the deterioration of science and math education to failure by schools to implement programs effectively; however, scientists who directed the programs failed to take account either of analogous developments in other educational fields or of changes in the philosophy of science. Major changes in science and math curricula beyond a return to teacher retraining are unlikely, but perhaps an increased emphasis on scientific experimentation' as opposed to the rote memorization of scientific facts will promote student interest in the sciences (Duschl, 1986).

Over the next decade, the Natinal Science Foundation expects to spend a total of $25 million on a program to improve science education, according to Lewis (1987). As a first step, Lewis explained how the foundation awarded $6.6 million in grants to three private research centers that worked with textbook publishers and selected schools to develop new teaching materials for the sciences. Also being developed is a telecommunications system that would allow students in about four thousand schools throughout the country to gather and share data on topics such as acid rain. Lewis emphasized that this funding is necessary to advance science instruction beyond the rote memorization of information, which changes from decade to decade anyway. She also points out that even with the development of new science curricula, the teachers must be retrained to teach science using an investigative approach, incorporating hands-on experiments to stimulate student involvement.

In a year long study completed in a high school is Austin, Texas, Turpin (1989), explained how she incorporated computer software into her science instruction. Her test results showed a ten percent increase in student performance over other science classes that had been instructed without the use of the computer lab and science software. Turpin reported that although the use of the computers by the students was always a part of class instruction, many students opted to give up study hall time, come in before classes, or remain after school to have additional time working with the software.

Loiry (1985) was involved in four years of science research and programs in high schools throughout the state of Texas. During that time, he served as a participant, a judge, or an observer in local, regional, state, and international science and engineering fairs, paper competitions, and as a member of science academies and clubs. His findings after four years of involvement are numerous and include the following: student interaction with others is greatly enhanced; research projects bring together students, teachers, parents, professionals, and the public; the community becomes more interested in what is happening in the school system; it helps to promote self awareness within the participating students. Finally, Loiry stated that science research and programs are of great academic value because they provide a creative and productive outlet for students who find it difficult to relate to the traditional classroom atmosphere.

Beardsley's study (1988) entitled, "The Science Report Card" concluded that U.S. students have a generally poor understanding of science. The study, which was based on a sample of some 13,000 secondary-school students, indicated that students at this level had improved somewhat since 1982. Among 17 year olds who were taught with the traditional approach to science, 1 in 13 displayed only a slight degree of sophisticated understanding. When compared to those students who were instructed using the investigative approach to science, test results indicated that the traditionally instructed students lagged behind significantly in their understanding of scientific concepts.

The review of the literature in this problem area failed to adequately reveal any one particular strategy or approach to improving the effectiveness of science teachers. The most practical approach appeared to be an amalgamation of methods. In conducting this study, this writer has been made congnizant of two limiting factors that will significantly impact the outcome objectives, namely time and money.

After further deliberation, this writer determined the primary task of this study was to be the development of a teacher handbook, designed to provide guidelines as well as practical and relevant information for the implementation and administration of a comprehensive science research program. With restrictions placed on the high school teacher, such as large class sizes, multiple preparation of courses, lack of appropriate facilities, and limited planning time during the workday, this handbook will serve as a means of overcoming these limitations.

# Chapter III

## Methodology

Approval for the implementation of this practicum was granted by Dr. Fred Carter, the author's advisor, on March 16, 1990. Subsequently, work began on a comprehensive teacher resource handbook. The handbook was developed for science teachers at the target school. Included in the introductory material of the handbook is an overview, introduction, discussion of facilities needed for research, and a list of scientific research equipment available at the central science office within the target district.

Once underway, the author divided the practicum implementation into three categories: planning, development and execution, and evaluation. A brief description of each category is included on the following page.

Planning: In this segment of the project, the author developed and administered a pretest to the 15 participating teachers within the target group. The results of the test were used to determine the types of materials to be included in the handbook.

Development/Execution: In this phase of the project, the author developed the materials to be included as part of the science research handbook. Through the use of workshops, slide presentations, and individual tutoring, the author instructed the participating teachers on how to incorporate the instructional materials as a supplement to each teacher's curriculum.

Evaluation: The author administered a posttest to the 15 participating teachers. The results from the pretest were compared to posttest results and evaluated. A comparison between other performance data accumulated prior to the project to data acquired at the end of the project was also included in this segment.

A more detailed description of the project components is as follows:

**Planning**: Having received permission to begin the practicum implementation, the author held a brief meeting with the 15 participating teachers. The meeting was conducted during lunch break on the 20th day of March, 1990. During the meeting, oral instructions concerning the administration of a pretest were discussed. Teachers were told that the test would be given on March 22, 1990, and that the test could be completed during any available planning period throughout that day.

Having been given a 48 hour notice, each teacher was prepared to take the test. When the test day arrived, the author gave each teacher a copy of the test at the beginning of the workday. Written instructions were given along with a plain envelope that was used to return the test to the author's classroom by the end of the workday. The prestest, developed by the author in conjunction with the Science Department Head, consisted of 25 scientific questions, all of which pertained to background knowledge a teacher would be required to have in order to effectively teach science research.

As the day progressed, the tests were received from the individual teachers. By the end of the day, 100% of the tests were submitted. On March 24, 1990, the tests were graded and the results were compiled for evaluation.

Development/Execution: Actual development of the handbook began on March 25, 1990. An evaluation of the pretest results revealed that the participating teachers were deficient in many areas of science research, most notably, the questions pertaining to statistical analysis of scientific data. It is for this reason that the author concentrated his efforts on developing Unit II of the handbook with great detail. This section deals with the subject of statistical analysis and when it should be applied to science research.

After having decided on what types of materials should be included in the handbook, the author developed a timeline in which to execute the implementation of the resource materials.

The events that took place are as follows:

**Week 1:**

Since many of the participating teachers have never had any of their students participate in science fair competition, the author gave a slide presentation in which research projects that appeared in the 1988 target districts Annual Science Fair were featured. The teachers responded favorably to the presentation and expressed a strong interest in receiving a copy of the resource handbook. At the conclusion of the meeting, a date was decided for an after school teacher inservice to discuss the curriculum objectives contained within the handbook.

**Week 2:**

A teacher inservice was held after school to discuss the curriculum objectives contained within the handbook. At this time, the author distributed the first section of the handbook to the 15 participating teachers. The materials contained within this section are listed in outline form in order of their appearance in the handbook.

The outline is as follows:

I. Overview
II. Introduction
III. Science Research Program Objectives
IV. Facilities
V. Program Reference Sources
VI. Available Research Equipment

The lecture-discussion method was employed by the author in order to cover the materials outlined above. Knowing that many of the participating teachers had little experience in teaching science research, the first item covered was the overview of the science research program, followed by a brief discussion concerning the importance of the handbook. This discussion led to the coverage of the program objectives and facilities required in order to effectively teach science research.

Knowing that it would be virtually impossible to incorporate every facet of science research in the handbook, the author included a list of references that would assist the teachers in the development of a successful research program. Some of the references that have been included were suggested by members of the math department within the target school. During the development of the handbook, the author also consulted with teachers experienced in the operation of science fair competitions. Additional references from these teachers have also been included.

The teacher inservice ended with a discussion on the types of scientific apparatus available for use through the target districts central science office. Nine of the participating teachers were not even aware of the existence of the apparatus discussed and were very appreciative of the information.

**Week 3:**

The development of Unit I had just been completed by the author and was distributed to each teacher. This section of the handbook was especially designed to cover an area of weakness. Having determined that the teachers did not score well on this section of the pretest, the author developed a step by step procedure for teachers to follow. Included were instructions for teachers on how to get their students started on a research project.

Also included were specific instructions on how to do science research as well as a list of suggested topic areas for projects.

Each step of the research paper was fully explained for the benefit of those teachers with little experience in teaching research. While it was not necessary to hold a teacher inservice for the presentation of this unit, the author had to work individually with five teachers in order to explain the parts of a research paper.

**Weeks 4, 5:**

On Monday of the fourth week, the author distributed a copy of Unit II to each participating teacher. This unit dealt with the use of statistics for scientific analysis of data acquired in researching a problem. This area of the handbook was carefully written to address the area of greatest weakness, as determined by the evaluation of the pretest results. It was during this point in the practicum implementation that the author encountered problems with instructing the teachers on the use of the handbook.

After two hours of discussion concerning the use of statistics in research, the participating teachers were expressing concern about the statistical tests included in the handbook. Eight teachers were not familiar with the statistical tests being covered, and consequently, did not feel comfortable in attempting to teach their students. While the remaining seven teachers had demonstrated a mastery of the material, there was not enough time to continue with the inservice. In order to overcome the problem, the author decided to work with the teachers on an individual basis. Individual arrangements were made with those teachers who did not feel comfortable with the material and tutoring was completed on a one to one basis.

Only nine of the fifteen participating teachers decided that it was appropriate to teach statistics to their students, but all fifteen teachers expressed their gratitude for having learned new material.

**Weeks 6, 7, and 8:**

A teacher workshop was originally planned for the beginning of the seventh week, however, the author had to make a course correction at this time. The course correction was necessary due to the lack of available time on the part of the participating teachers. Instead, Unit III and Unit IV were disseminated to each teacher on an individual basis. Since the materials within these two units required little explanation, each teacher was asked to meet with the author on an as needed basis. Unit III consisted of research related skills and activities that were incorporated into each teacher's classroom instruction over the three week period. The subject areas taught are as follows:

I. Safety guidelines for science labs
II. Science apparatus for student use
III. Review of metric units
IV. Significant figures in calculations
V. Scientific Notation
VI. Temperature scales and conversions
VII. Review of graphs
VIII. Recipes for preparing stains
IX. Review of solution concentrations

Unit IV consisted of science fair information and was self explanatory.

Since no competitions were being held within the target district or school at this time, this information was used to acquaint the participating teachers with the information they would need in preparation for the following school year.

**Weeks 9 and 10:**

During the last two weeks of implementation, the author consulted with the participating teachers in order to assess student needs. The author stayed after school each day to help students with their individual research projects. The students were assisted with the process of analyzing their research data. Since the statistical techniques being applied had been taught several weeks ago, it was necessary to tutor some of the students in order to refresh their skills.

The author spent many hours assisting the teachers with the reading and grading of student research papers. This was necessary in order to provide the 15 participating teachers with study time in preparation for the posttest. The posttest was administered on May 30, 1990.

Each participating teacher was allowed the entire day to complete to test. The honor system was used for the administering of the test, and teachers were encouraged not to use the handbook during the test. By the end of the day, each teacher had turned in their own copy of the posttest. The author graded and evaluated the posttest on June 2 and June 3, 1990.

Evaluation: The evaluation of the practicum was conducted by the author and based, in part, on the results of the posttest that was administered on May 30, 1990. All 15 participating teachers submitted a completed test. A comparison of the results between the pretest and posttest was used to determine the overall percentage of improvement.

A study of the number of students that have enrolled in science courses for the upcoming school year was also used as a means of evaluating the success of the program. Finally, a general evaluation was conducted, based upon the impressions and contentions made by the author, students and participants (members of the target group). A general comment form was issued to the participating teachers in order to document and evaluate all comments.

## Chapter IV

## Results

As a means of documenting the anticipated results of this study, the author developed six outcome objectives. The first objective involved the evaluation of results obtained from a pretest-posttest comparison. Originally stated, the author claimed that the results of this comparison would demonstrate that eighty percent of the teachers participating in the programmed instruction would increase their background knowledge in the area of science research instruction.

In order to effectively evaluate the test results, the author compiled the test scores into a statistical format. The chart containing the test scores is listed on the following page. The raw scores are listed in the first two columns, followed by the same scores in ascending order.

## COMPILATION OF PRETEST AND POSTTEST RESULTS

| RAW DATA | | ORDERED DATA | | DIFFERENCE FROM MEAN | | SQUARE OF DIFFERENCES | |
|---|---|---|---|---|---|---|---|
| $X_1$ | $X_2$ | $X_1$ | $X_2$ | $X_1$ | $X_2$ | $X_1$ | $X_2$ |
| 20 | 23 | 14 | 19 | -4.7 | -3.7 | 22.09 | 13.69 |
| 18 | 24 | 16 | 20 | -2.7 | -2.7 | 7.29 | 7.29 |
| 22 | 25 | 16 | 20 | -2.7 | -2.7 | 7.29 | 7.29 |
| 18 | 20 | 17 | 21 | -1.7 | -1.7 | 2.89 | 2.89 |
| 16 | 21 | 17 | 22 | -1.7 | -0.7 | 2.89 | .49 |
| 22 | 23 | 18 | 23 | -0.7 | 0.3 | .49 | .09 |
| 17 | 19 | 18 | 23 | -0.7 | 0.3 | .49 | .09 |
| 14 | 22 | 19 | 23 | 0.3 | 0.3 | .09 | .09 |
| 21 | 25 | 19 | 23 | 0.3 | 0.3 | .09 | .09 |
| 19 | 23 | 19 | 24 | 0.3 | 1.3 | .09 | 1.69 |
| 23 | 24 | 20 | 24 | 1.3 | 1.3 | 1.69 | 1.69 |
| 16 | 24 | 21 | 24 | 2.3 | 1.3 | 5.29 | 1.69 |
| 19 | 23 | 22 | 24 | 3.3 | 1.3 | 10.89 | 1.69 |
| 17 | 20 | 22 | 25 | 3.3 | 2.3 | 10.89 | 5.29 |
| 19 | 24 | 23 | 25 | 4.3 | 2.3 | 18.49 | 5.29 |

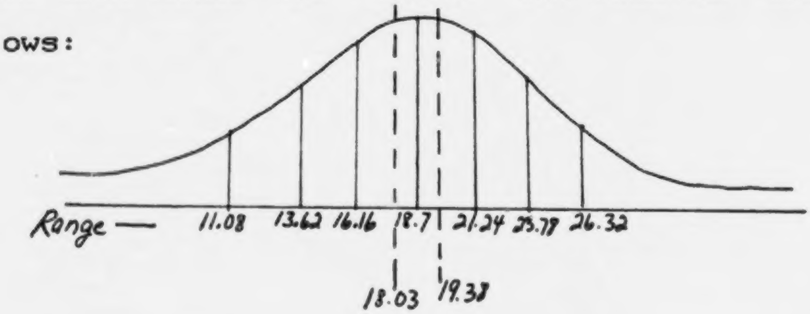
$X_1$ = This symbol denotes the original 15 scores from the pretest. The scores may be read by referring to the first column labeled RAW DATA. The same scores have been listed in ascending order and may be read by referring to the third column labeled ORDERED DATA.

$X_2$ = This symbol denotes the 15 scores from the posttest. The scores may be read by referring to the second column labeled RAW DATA. The same scores have been listed in ascending order and may be read by referring to the fourth column labeled ORDERED DATA.

arithmetic mean of $X_1$ = 18.7
arithmetic mean of $X_2$ = 22.7

sum of squared differences of $X_1$ = 90.95
sum of squared differences of $X_2$ = 49.35

A comparison of the pretest raw scores to that of the posttest raw scores revealed that 100 percent of the participating teachers improved their background knowledge in the area of science research. The greatest amount of improvement documented was 20 percent with an average improvement of 16 percent. While the test results clearly demonstrated that the author's first objective had been met, a more thorough form of statistical analysis was employed by the author. In order to substantiate the reliability of the test data, the range of pretest scores was plotted on a Bell Curve. The arithmetic mean of 18.7 (prestest mean) was used as a basis for determining the standard deviations as represented by the area under the curve. The results are as follows:



standard deviation (S.D.) = +,- 2.54

standard of error (S.E.) = +,- .67

One standard deviation of (+,- 2.54) when added to the sample mean (18.7) revealed a range of 16.16 to 21.24. Within one S.D. lie 11 of the 15 original test scores or 73% of the scores. Statistically, only 68% of the original scores would have to fall within one S.D. in order for the data to be considered valid. Further analysis of the test data revealed that 100% of the test scores fell within three standard deviations of the mean. Usually, 99% of the scores would have to fall within the range of three standard deviations in order for the test scores to be considered valid.

The results of the pretest-posttest comparison clearly pointed out to the author that not only were the tests valid, but that the handbook developed for the teachers proved most helpful in strengthening their background knowledge in the area of science research.

The second objective dealt with the development of a school science fair. Unfortunately, that objective was not met. Although the participating teachers remarked on how helpful the research handbook was in assisting them with their instruction of science research, the lack of time was an intervening variable that proved to have a negative effect. While 78 students did complete a science project, there simply was not enough time left in the school year to hold a science fair. However, the teachers agreed that the development of a school science fair in the upcoming school year would be a major priority for the science department. Additionally, the 78 students who completed science projects would be allowed to further develop the same projects and enter them in next years science fair.

The third objective identified by the author addressed the problem of student enrollment. The author stated that by incorporating science research instruction into each science teachers curriculum, more students would become interested in taking science classes as electives. Documentation of this objective showed that the number of elective courses being offered next year has increased from seven advanced elective courses being offered this year to a projected ten advanced elective courses to be offered next year.

Another problem addressed in the study included a lack of student enrollment in science research classes at the target school. It was stated by the author that the availability of a research handbook would provide teachers with limited planning time, and multiple course preparations, with the materials needed to teach science research. As a result, the teacher currently assigned to teaching one section of science research will be teaching two sections of that class next year, along with a second course preparation in Biology. The projected enrollment for next school year, as reported by the guidance department, necessitated the addition of that second section of science research.

The fifth objective dealt with the policy of the science department within the target school. In the past, the science department did not require that teachers teach science research as part of their regular subject matter. Since the development of the handbook, a new science department policy has been adopted. Because the teachers no longer have to spend hours of valuable planning time gathering instructional materials in order to teach the techniques of science research, it was generally agreed that science research should be incorporated into every laboratory oriented science class. This new policy will be instituted next year and will require that every student enrolled in these classes complete a science research project. The teachers within the science department, as well as the school administrator assigned to oversee the department, are very excited about the new policy.

The sixth and final objective dealt with the attitudes of the teachers and their lack of involvement in district level science competition. This objective was met due to the change in science department policy. Since the teachers of laboratory oriented classes will now be required to provide science research instruction along with the traditional curriculum, many students will be actively involved with research projects. These student generated projects will become part of the first school science fair. Several of the winning projects will be entered in the district level science fair competition. The number of projects to be entered will be determined by the number of students enrolled at the target school.

In discussing the new policy with the members of the science department, the author was praised by the teachers for developing the research handbook. Most of the teachers expreseed their confidence in the handbook and stated that they were enthusiastic about the upcoming school year.

In conclusion, this practicum clearly showed the need for a research handbook. The key element for success of this study was in providing the teachers with a comprehensive manual that included explanations of what science research is all about, understandable literature on statistical analysis, and strategies and activities on scientific techniques.

# Chapter V

## Recommendations

Having completed the implementation of the practicum, the author was satisfied with achieving a moderate degree of success. In a discussion with the science department chairperson, the author recommended that a copy of the handbook be made available to other science teachers within the target district. The department chairperson agreed, and assured the author that the recommendation would be discussed at the next district level science curriculum committee meeting. The meeting is scheduled to take place around the third week in August of 1990.

A second recommendation made by the author concerned the policy of the science department within the target school. Although it was agreed that science research instruction would be incorporated into every laboratory oriented science course in the upcoming school year, student participation in a school wide science fair will be optional. It was recommended that student participation in the science fair be made mandatory for all students enrolled in advanced science classes. Furthermore, it was recommended that every high school in the district adopt the policy of sending student entrants to district level science fair competition.

Additionally, the author recommended that the target school district allocate funds to develop teacher effectiveness training workshops. Observations of teacher performance during the implementation of the practicum clearly demonstrated a need for additional teacher training in the area of science research education. Better educated teachers will strengthen science education within the target district. Students will learn a variety of skills which they would not be taught in a traditional curriculum. Finally, the development of science research education is of great academic value because it provides a creative and productive outlet for students who find it difficult to relate to the conventional classroom atmosphere.

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# Appendices

# Appendix A

## Pretest on Science Research Skills

## Science Research
## Pretest

DIRECTIONS: For each of the items listed, choose that which is the best response. Note that for each question or statement, there is only one correct response. Certain items require calculations to be completed. Place all responses on the blank spaces provided on the test.

1. A student measured the molecular mass of a compound five times and obtained the following five results:

    1. 98.0 g/mole
    2. 96.5 g/mole
    3. 97.1 g/mole
    4. 100.2 g/mole
    5. 98.3 g/mole

    Calculate the mean molecular mass of the compound. ans.________

2. Given the following set of values: 98, 95, 90, 86, 85, 76, 73, 66, 64, 52, 32, 28 and 24, you should be able to determine the following answers:

    What is the value of $X$ ? ans.__________
    What is the value of $n$ ? ans.__________
    What is the value of $X^2$ ? ans.__________

3. A hypothesis is a statement that

    a. is always true and acceptable.
    b. is a deduction.
    c. is simple common sense.
    d. may be the answer to a question. ans._____

4. When calculating the degrees of freedom (d.f.) for the following formula, assuming that the two research groups being compared had 35 individuals each, which one of the following formulas would you use?

formula:

a. d.f. = n-1
b. d.f. = n
c. d.f. = n+1
d. d.f. = n+35 ans._____

5. Calculate the variance, standard deviation and standard of error for the following groups of data:

| EXPERIMENTAL GROUP | CONTROL GROUP |
|---|---|
| 50.7 | 69.8 |
| 54.9 | 53.4 |
| 54.3 | 66.1 |
| 44.8 | 48.1 |
| 42.2 | 35.5 |
| | 27.3 |
| | 20.1 |

variance ___________
standard of error_______________
standard deviation_______________

The next five questions are based on the following data:

A chemical called **BW** is believed to prevent colds. To test this belief, 20,000 volunteers were divided into 4 groups, and each individual took a pill every morning for one year.

| GROUP | NUMBER IN GROUP | CONTENTS OF PILL | % DEVELOPING COLDS |
|---|---|---|---|
| I. | 4750 | 5 grams of sugar | 20% |
| II. | 4750 | 5 grams of sugar<br>1 gram of BW | 19% |
| III. | 4750 | 5 grams of sugar<br>3 grams of BW | 21% |
| IV. | 5750 | 5 grams of sugar<br>9 grams of BW | 15% |

6. Which group served as the control for this test?

   a. I
   b. II
   c. III
   d. IV ans.________

7. From the data showing percent of individuals developing colds in each group, one can conclude that sugar

   a. reduced the number of colds.
   b. increased the number of colds.
   c. and BW are effective in the prevention of colds.
   d. and 9 g of BW apparently did help prevent colds.

   ans.______

8. In interpreting these results, it would be helpful to know the

   a. chemical nature of BW.
   b. kind of sugar used in the pills.
   c. average age of the volunteers.
   d. characteristics of the people in each group.

   ans.______

9. If it were later pointed out that the first 3 groups lived in Chicago and group 4 in Florida, then

    a. one would question the value of BW in preventing colds.
    b. this additional fact would not affect the results.
    c. it would show that more BW was required to prevent colds.
    d. an increase in amount of BW used in Chicago would prevent colds.

ans.______

10. One investigator interpreted the data to mean "BW and sugar does not significantly reduce the chance that you will catch a cold." His interpretation of the data would change if group (s)

    a. I, II, and III all contained 5750 people.
    b. II had been given 3 grams of BW.
    c. IV consisted of old, sick people.
    d. III consisted of only athletes.

ans.______

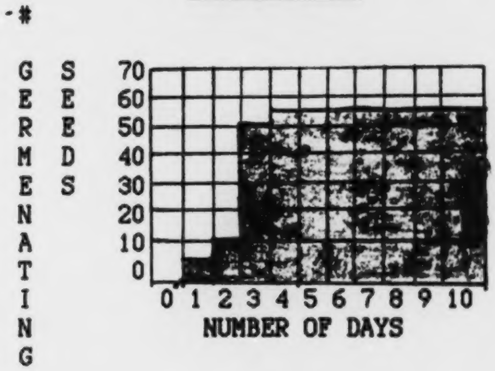
11. A hypothesis should not only account for the known facts in a problem, but should also

    a. record the data.
    b. compare observations.
    c. predict new information.
    d. review the history of science.

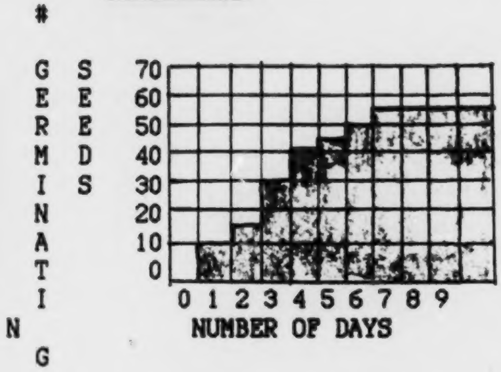
ans.______

---

An experiment was conducted on the germenation of seeds. The data ascertained from the experiment are graphed on the next page. Answer questions 12 through 15 by referring to the data provided by the graphs.



SEEDS SOAKED FOR 24 HOURS
RADISH SEEDS



SEEDS SOAKED FOR 24 HOURS
BEAN SEEDS

12. A generalization that can be made about the data is that

    a. 24 hours is the best soaking period for radish and bean seed.s
    b. radish seeds germinate more rapidly than bean seeds.
    c. the bean seeds has a steady rate of germination.
    d. most bean seeds of this kind require 6 days to germinate.

    ans.______

13. If you were to advise a student about when to expect most soaked radish seeds of this variety to germinate, you should say

    a. 2 days after planting.
    b. 1 day after planting.
    c. 3 days after planting.
    d. at least 5 days after planting.

    ans.______

14. Which factor is the variable in this experiment?

    a. The period of the soaking
    b. The dishes that the seeds were planted in
    c. The rate of germination
    d. The kind of seed used.

ans.______

15. If you wished to test the hypothesis that atomic radiation slows down the rate of radish seed germination, which of the following experimental designs would be best to use?

    a. Use 25 radish seeds and 25 bean seeds and compare results.
    b. Plant 50 irradiated seeds and note the effects of the radiation.
    c. Plant 25 irradiated seeds and 25 normal seeds at the same time and compare results.
    d. Plant 25 normal seeds, note results; then plant 25 irradiated seeds, compare results.

ans.______

---

Seeds of three species of plants were treated with fungicide. In each of six large petri dishes, 50 seeds were placed on moist filter paper and kept at room temperature. The number of seeds germinating in each dish is recorded in the table below.

| | IN LIGHT | IN DARK |
|---|---|---|
| Species X | 42 | 7 |
| Species Y | 14 | 36 |
| Species Z | 35 | 37 |

The next five items are statements which were suggested as hypotheses being tested by the experiment listed on the previous page. Judge each according to the key.

KEY: A. A hypothesis being tested by this experiment
B. A hypothesis NOT being tested by this experiment
C. This statement is not a hypothesis.

_____16. Some of the seeds in each dish germinated.

_____17. Light is a factor which influences germination.

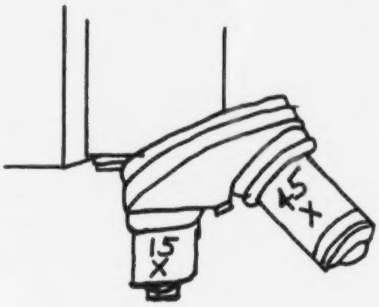
_____18. Temperature is a factor which influences germination.

_____19. Different species of plants have seeds which differ in their germination requirements.

_____20. Amount of moisture affects germination.

---

Assume that the diagram below represents the nosepiece and objective of a microscope. Under low power magnification, 63 evenly distributed yeast cells can be seen on a slide.



_____21. About how many of these same yeast cells will you see when you turn the nosepiece to high power?

a. 7
b. 21
c. 126
d. 189

_____22. With a 10X eyepiece, the yeast under high power will be magnified

a. 10x
b. 150x
c. 450x
d. 675x

_____23. Which of the following statements best explains why living organisms under magnification move in and out of focus?

a. The source of light for the micro- is poor.
b. The organisms move to different levels
c. The observer does not make careful and steady measurements.
d. The microscope goes out of focus with time.

_____24. After a hypothesis is stated, the next logical step is to

a. define the problem.
b. develop experiments and observations to test the hypothesis.
c. establish arguments for and against the problem.
d. accept or reject the hypothesis.

_____25. The most reliable information as to what is going on in scientific laboratories at the present time is to be found in

a. science textbooks.
b. newspapers.
c. popular magazines, such as Reader's Digest.
d. journals of scientific societies.

---

COMMENTS:

If any mistakes have been noticed during the taking of this test, please notify me as to the question number involved and the nature of the error. Any additional comments may also be written in the space below. Thank you for your cooperation in this matter.

# Appendix B

# Compilation of Pretest and Posttest Results

The following results were obtained by testing the individual teachers within the target group. They represent raw scores achieved on a 25 question test.

### COMPILATION OF PRETEST & POSTTEST RESULTS

| TEACHER NUMBER | RAW SCORES | | ORDERED SCORES | |
|---|---|---|---|---|
| | * $X_1$ | $X_2$ * | $X_1$ | $X_2$ |
| I | 20 | 23 | 14 | 19 |
| II | 18 | 24 | 16 | 20 |
| III | 22 | 25 | 16 | 20 |
| IV | 18 | 20 | 17 | 21 |
| V | 16 | 21 | 17 | 22 |
| VI | 22 | 23 | 18 | 23 |
| VII | 17 | 19 | 18 | 23 |
| VIII | 14 | 22 | 19 | 23 |
| IX | 21 | 25 | 19 | 23 |
| X | 19 | 23 | 19 | 24 |
| XI | 23 | 24 | 20 | 24 |
| XII | 16 | 24 | 21 | 24 |
| XIII | 19 | 23 | 22 | 24 |
| XIV | 17 | 20 | 22 | 25 |
| XV | 19 | 24 | 23 | 25 |
| | | TOTAL = | 281 | 340 |

* $X_1$ = Represents Prestest Results

* $X_2$ = Reprersents Posttest Results

arithmetic mean of $X_1$ = 18.7
arithmetic mean of $X_2$ = 22.7

## Appendix C

## Resource Handbook for Science Research

# resource
# handbook

# for

# science research
# instruction

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Gratitude is also extended to Dr. Stephen Siplet for giving me a second chance with the development and implementation of this handbook. Without his kindness and generosity, this experience would not have been possible.

A special thank you to my wife Helen and daughter Janeene for providing me with moral support throughout the many months of development that went into this handbook.

# OVERVIEW

This science research curriculum is intended to be comprehensive, versatile, and applicable to secondary science teachers in general and science research teachers in particular. Included in the introductory material are suggestions for evaluating the student, time references for recommended due dates of activities and a list of materials available at the central science office.

The curriclulum is divided into four major units. Unit One, Writing the Research Paper, will help in introducing the parts of a research paper. Several research articles have been provided for use in the practice of critiquing published scientific articles. Unit Two on Statistics includes a section dealing with the application of probability and statistics. Sample problems have been included for drill and practice as well as for the purpose of homework assignments.

Unit Three contains selected topics necessary in science research. Extensive exercises designed to develop and strengthen laboratory skills as well as mathematical processes are included, lending themselves to immediate reproduction on a Xerox machine. The answers pertaining to each worksheet are included in the margins for the benefit of the teacher.

The final section, Unit Four, contains pertinent information for science competitions.

# UNIT I

## INTRODUCTION

It is a known fact that very often the needs of the talented high school science student cannot be adequately met. Restrictions placed on the high school teacher, such as large class sizes, multiple preparation of courses, lack of appropriate facilities and equipment, inadequate background and heterogeneous grouping of students often combine to make it impossible to provide the additional experiences that could challenge today's science student. If unchallenged, these students may turn to other areas of interest for stimulation and potential scientists could be lost.

The science research program is designed to provide the exceptional, advanced, and/or creative student an opportunity to develop and utilize techniques for scientific research and investigation that will be useful and essential to their careers in science.

The intent of this handbook is to provide guidelines as well as practical and relevant information for the implementation and administration of the program. Since the grade level of this program will vary depending on the instructor, some of the information included as skill sheets may not be appropriate to every course. Each individual teacher may include or omit these exercises wherever necessary.

## SCIENCE RESEARCH PROGRAM OBJECTIVES

One goal of this program is to give the student an opportunity to develop increasing responsibility in directing his own efforts and carrying out investigations. The student should develop an investigative profeciency involving mastery of the following skills:

a) identification of problem areas
b) location of pertinent information
c) development of an experimental design
d) observation, collection and analysis of data
e) formulation of a conclusion based on experimental data
f) application of conclusions or principles to new situations
g) writing a research paper which covers the research topic adequately and which uses the format outlined in this handbook.

A second goal involves the development of techniques, procedures and manipulative skills necessary for successful laboratory work. Included among these are:

a) identification and proper use of apparatus
b) budgeting time wisely
c) development of procedural and organizational skills necessary for standard laboratory work
d) the exercising of proper safety procedures in and around the science laboratory.

The last goal is to foster a number of positive attitudes in student behavior including:

a) a mature and cooperative approach to scientific research
b) an understanding and acceptance of the fact that experimental research is demanding and time consuming and that at times, extracurricular activities may have to be sacrificed
c) an inquisitive approach to problem solving, enthusiasm for science competitions and interest in scientific knowledge.

## FACILITIES

1. Laboratory rooms must be operational.

2. An adequate budget for the purchase of expendable supply items should be available.

3. Basic equipment should be in good working order.

4. A special area must be established whereby lab setups and equipment can remain safely in place and can be accessed by the students at various times.

5. Adequate funding for qualified students to attend identified science/math competitions, i.e., transportation, lodging, food, and chaperones.

6. A centrally-located county resource center should be established to provide student access to sophisticated analytical equipment not necessarily available in the high school laboratory.

# PROGRAM REFERENCE SOURCES

The following books are highly recommended to assist the program instructor in the development of a successful research program.

1. Nuts and Bolts: A Matter of Fact Guide to Science Fair Projects.
   The Science Man
   4738 North Harlem
   Haarwood Heights, IL 60656

2. The Practical Statistician: Simplified Handbook of Statistics
   Brooks/Cole Publishing Company
   Monterey, California

3. Educational Research: Competencies for Analysis and Application
   Charles E. Merrill Publishing Company
   Columbus, Ohio 43216

4. Statistics: An Intuitive Approach
   Brooks/Cole Publishing Company
   Monterey, California

5. Winning With Science: The Complete Guide to Science Research and Programs for Students
   Lorry Publishing House
   635 South Orange Avenue, Suite 6
   Sarasota, Florida 33577

6. Abstracts for past International Science and Engineering Fair
   Science Service
   1719 North Street, NW
   Washington, D.C. 20036

7. Qualitative Inorganic Analysis
Prentice-Hall
Englewood Cliffs, New Jersey 07632

8. Principles and Procedures of Statistics with Special Reference to the Biological Sciences
McGraw-Hill, New York

9. Handboook: Florida Junior Academy of Science and Florida Science Talent Search
Dorothy Henley
Ft. Lauderdale, Florida

## AVAILABLE RESEARCH EQUIPMENT

The following equipment is available for use from the Central Science Office. It may be obtained by calling 765-6040.

### Research Equipment

C R C Laser Books (2 books)
Water Pollution Analysis Kit
Hall Effect Gaussmeter
Hi Strength Magnetizer
Function Generator plus 4 Ultrasonic Transducers
Amplifier Power Supply
Lasers (ML-869) (2 available)
Canon T-Mount Camera Adapter
Fiber Optics Kit
Refractometer (Salinity)
Incubator (for Eggs)
EKG Selector Switch- EKG Accessory Package
Bio-Amplifier (comes with cable and adaptor set)
EEG Amplifier
Aerodynamic Balance
Light Meter plus Multiplier Disc (Weston)
Stimulating Electrodes, Nerve Chamber and Electronic Stimulator
Dual Channel Strip Chart Recorder
Griffin Wind Generator
Photoelectric Colorimeter-CENCO
Microbiological Incubator
Millipore-Filter Basic Equipment
Portable pH meter
Weatherscope Station
Measurement Module

Radiological Survey Meter
Radioactivity Demonstrator
Electronic Balance
Anemometer-Windsocpe
Weather Study Center
Force Table
Spectrometer and parts for Force Table
Spectrophotometer Colorimeter
Photoelectric Colorimeter
Gas Chromatograph
Geology Stream Table
Vacuum Pressure Pump
Bell Jar
Recording Barometer
Recording Thermometer
Photomicrographic Camera
Biological Model Set
Dual Trace Oscilloscope
Bio-Amplifier/Supply
Incubator
Inclined Research Binocular Microscope
Stereo Microscope/Dual Illumination

These items are avalable in addition to the various apparatus that may be found within the school. For a complete list of materials on site, see the department chairperson.

## HOW TO GET YOUR STUDENTS STARTED ON THEIR PROJECTS

Making a classroom a resource center is one of the most stimulating ways of getting students interested in developing a science project. This can be accomplished by really orgainzing the room with a library, varied bulliten boards, scientific models that arouse their curiosity, and file cabinets that the students might have access to during their class time. When possible, a wide variety of books should be available in the room. Many times, students have science books around the house that can be used in the classroom and books no longer on the state adoption list are usually just collecting dust in some backroom and warehouse. These books could become most valuable in the classroom as resource materials.

In addition, most school libraries contain a good selection of books on experiments and projects. Do not forget to use magazines, newspapers, and programs on TV as sources for projects. Also, an exploratory day or two in the library for the student is usually an invaluable experience. Remember, the hardest part for students in writing a research paper is establishing an original problem. Do not hesitate to invite students who have won past fairs to talk to your classes about how they came up with their ideas. Finally, you may want to give a slide presentation to introduce the students to what science fair competiton is all about. This usually gets the students rather excited. I have a personal slide show that is readily available and may be borrowed at any time. Feel free to call me at 370-1616.

Do not expect that all the students will have an idea within a day or so. Be patient and enthusiastic, as it will take some students longer that others. Perhaps small groups can be formed from those who have truble selecting a project and ideas and discussions can be presented.

Once the students have come up with an idea, they should begin to develop a title for their project. This may be changed many times before the project is actually completed. The students should also include some information about the direction they would like their project to take as well as some ideas about how they are going to conduct their experiment. At this time, it is a good idea for the teacher to collect this paper, review their ideas, and make the necessary pertinent comments to help steer the child in the correct direction. In some cases, the project ideas will be much too broad in scope and should be narrowed down and simplified if possible. If you provide the student with some immediate feedback as to the feasibility of their project, this will help to get them started while their interest is high. Allow about one week or so for most of the students to develop a project idea.

## HOW TO DO SCIENTIFIC RESEARCH

Scientific research is really a skill that should be developed slowly over a period of time. The teacher should review periodically, the progress being made by each student as the research papers are being written. One practice that works well is to establish a time schedule whereby various parts of their papers are due for teacher evaluation. If this practice is adhered to, by the time the student is ready to submit his paper and project for the final grade or for the school science fair, you will have had an opportunity to review each part of the students research paper.

Naturally, all students will need some guidelines about how to do some preliminary research. This involves going to the library and becoming acquainted with the wide variety of areas that could be covered for a science fair project. Sources used to aid the student in finding general information about the various areas of science are listed below.

1. Card Catalogue
2. Reader's Guide to Periodical Literature
3. Wilson Search (CD ROM) on computer in the school's library
4. Science Encyclopedia
5. Newspapers, Magazines
6. Vertical File
7. Films, filmstrips, audio-visual presentations
8. Scientific Journals
9. Compton's Encyclopedia (CD ROM) on computer in the school's library
10. Student's own science textbook

## SUGGESTED TOPIC AREAS

Some areas of interest that may be examined by the student in preparing a science priject include the following:

### EARTH AND SPACE SCIENCE

- Mineralogy
- Oceanography
- Geochemistry
- Geology
- Petrology
- Archaeology
- Crystallography
- Environmental Science
- Radio Astronomy
- Astronomy
- Cosmology
- Metallurgy
- Meteorology
- Paleontology

### CHEMISTRY

- Organic Chemistry
- Inorganic Chemistry
- Physical Chemistry
- Chemical Technology
- Geochemistry
- Chemical Dynamics
- Structural Chemistry
- Bioenergetics
- Spectrology
- Chemurgy
- Reaction Geometry
- Electrochemistry
- Pharmacology
- Biophysical Chemistry

### ENGINEERING

- Transportation
- Aeronautics
- Astronautics
- Communications
- Architecture
- Biochemical Engineering
- Aerodynamics
- Mechanics
- Chemical Technology
- Electronics
- Civil Engineering

### COMPUTERS AND MATHEMATICS

- Logic
- Statistics
- Calculus
- Abstract Algebra
- Number Theory
- Biomathematics
- Geometry
- Topology
- Perception
- Complex Analysis
- Probability

## BIOCHEMISTRY

Molecular Genetics
Cellular Chemistry
Molecular Biology
Endocrinology
Immunology
Pharmacology
Ecology
Chemotherapy

## BOTANY

Plant Genetics
Plant Physiology
Agriculture
Ecology
Parasitology
Paleobotany

## ZOOLOGY

Genetics
Entomology
Ecology
Physiology
Parasitology
Anatomy
Embryology
Paleozoology
Protozoology
Invertebrate Neurophysiology

## HEALTH AND MEDICINE

Endocrinology
Neurology
Pathology
Pharmacognentics
Nutrition
Chemical Technology
Dentistry
Internal Medicine
Physiology
Serology

## SOCIAL AND BEHAVIORAL SCIENCES

- Anthropology
- Social Psychology
- Social Anthropology
- Cultural Anthropology
- Urban Sociology
- Physical Anthropology
- Educational Psychology
- Industrial Psychology
- Sociology
- Ecology
- Archaeology
- Psychology

## MICROBIOLOGY

- Bacteriology
- Genetics
- Cytology
- Serology
- Cell Physiology
- Virology
- Cellular Biology
- Protozoology
- Epidemiology

## PHYSICAL SCIENCES

Electrochemistry

Plasma Physics

Physical Chemistry

Optics

Holography

Astrophysics

Atomic Physics

Dynamics

Bioenergetics

Biomechanics

Fluid Mechanics

Solid State Mechanics

Nuclear Physics

Geophysics

Electronics

Molecular Physics

Statics

Biomedical Electronics

Ergonomics

## SKILLS NECESSARY IN WRITING YOUR RESEARCH PAPER

The research paper should be grammatically correct. The student should carefully check to make sure punctuation, spelling and word usage are all correct. This is where it is very helpful to have others check your work so that they may be able to spot errors that the student may have overlooked. Slang words and jargon should be avoided. The writer should pay particular attention to writing entirely in the third person and positively avoid the use of the word "I." In place of this word, the student can say, "In the opinion of this writer...," or "This researcher thinks," or "This author."

## MECHANICS OF THE RESEARCH PAPER

If at all possible, the student should type the research paper using the acceptable format outlined in most books for the writers of term papers. All graphs and data tables should be completed on the proper type of paper. All work should be double spaced and proper margins followed. Since the paper will be divided into separate sections, every section should be labeled in such a way as to show what the section is about and in a proper number sequence to coincide with the rest of the paper. The title of the project should be placed on the very first page. Each page of the report should be numbered and the abstract and table of contents page should be numbered using lower case roman numerals.

# THE RESEARCH FORMAT

Every research paper should be set up in the following manner:

TITLE PAGE
ABSTRACT
TABLE OF CONTENTS
STATEMENT OF PURPOSE
RESEARCH
HYPOTHESIS
EXPERIMENT
MATERIALS
PROCEDURES
DATA AND OBSERVATION
ANALYSIS AND DISCUSSION OF DATA
CONCLUSION
APPLICATION
RECOMMENDATIONS
BIBLIOGRAPHY
ACKNOWLEDGEMENTS
APPENDIX (OPTIONAL)

## THE TITLE

There is no specific way in which the title of a project is written. Sometimes it is a declarative statement and sometimes it is given in the form of a question. However, it is a good rule of thumb to keep the title short and concise. It may be necessary to revise the title several times throughout the paper to accurately reflect the exact nature of the subject being considered. The research scientist can refer to science journals to get some ideas of how to write the title. A couple of samle titles are offered here to illustrate the thoroughness that is necessary:

"A TWO YFEAR STUDY OF THE EFFECTIVENESS OF VARIOUS
TOOTHPASTES ON PLAQUE"

"THE USE OF ANIMAL BY-PRODUCTS AS A NUTRITIONAL
STIMULUS IN PLANT SEED GERMINATION"

"THE EFFECTS OF VITAMIN A, $B_1$, AND C ON
*STREPTOCOCCUS AUREUS*"

"OBSERVATIONS CONCERNING THE EFFECTS OF
CHLOROFLUOROCARBONS ON THE ENVIRONMENT"

"THE EFFECT OF VARIOUS CHEMICALS UPON THE GROWTH
OF THE BEAN PLANT"

## THE ABSTRACT

Following the title page should be the Abstract. An abstract is an overall summary of the experimental research done by the researcher. It usually answers the questions: What was the researcher trying to do? What actually happened? Of what significance are the actual findings? It should be 150 to 250 words in length. Words such as "the researcher", "the investigator", this exhibitor", are used instead of the first person "I." The abstract should be written in the past tense. The abstrct is written after the student has completed the project even though this appears in the front of the final paper.

## STATEMENT OF PURPOSE

Once the young scientist has chosen an area of science, a problem must now be identified. Ideas for specific problems can come from man sources. Visit libraries and browse through books, magazines, journals and specialized encyclopedias. Do not neglect films and filmstrips at your school. The young scientist should use imagination and curiosity whenever possible.

The experimenter must narrow the research to a very specific part of the total field or subject area being researched. If, for example, the researcher is interested in oceanography, the field must be narrowed down to such items as tidal pool life, the change of salinity on the respiration rate of a specific species of fish, etc... .

In the research paper, following the title page and abstract, the statement of purpose should follow on a page by itself. This statement should be a clear, concise, and declarative statement to identify the exact nature of the investigation. Nothing else should appear on this page. A concerted effort must be made in order to restrict the statement to a single sentence. If this is not possible, a second sentence may be used, but no more than two sentences.

## RESEARCHING THE TOPIC

Once the student has stated the problem, work can begin on researching background information. Research about the topic is necessary to privide the student and the reader with the latest developments in that field.

To gain the needed knowledge of the researcher's topic, much research must be done by the student. In addition to the wealth of information available in the school's library, the student may choose to use the public library in order to acquire additional sources of information. Some of the sources that the public library offers includes the following:

Card Catalogue
Book Catalogue
Encyclopedia of Associations
United States Government Manual
Director of Florida Government
The Florida Handbook
Congressional Director
The Municipal Director
Index File on Government Documents
Index File on Broward County Organizations
Comparative Guide to Science & Engineering Programs
American Men and Women of Science
Dictionary of Scientific Biography

Applied Science and Technology Index
Readers Guide to Periodic Literature

These sources are only a few which the library offers the young researcher. Other libraries available to the student include the local community college. Many of the local universities also have libraries that are open on Saturday and may be used by the public. Specialized libraries operated by local research organizations may be used if the student calls and asks for permission.

While gathering information about a given topic, the student must keep a record of the research being done. Unless the young researcher has a good system of record keeping, it should be recommended that index cards be used to keep tract of information being recorded. The student can keep a file of titles, authors, and information on 3 X 5 or 4 X 6 cards, alphabetized by author, so that they can be referred to quickly and conveniently. These cards may later be used to establish the bibliography for the research.

## HYPOTHESIS

Once the investigator has become an authority on the scientific problem, a brief hypothesis should be stated. A hypothesis has been described as a logical linkage between if and then. Consider the hypothesis that blood vessels are necessary for the function of some organ. Stated as a hypothesis. is is proposed that, if blood vessels are necessary for the action, then cutting the blood vessel leading to the organ should result in failure of the organ to function. The assumption will lead the investigator to design an experiment in which blood vessels are cut, then the results produced will be the data. If the data should show a loss in the function of the organ, the hypothesis is suported. If the organ continues to function, then the hypothesis is in doubt and must be rejected. It must be pointed out that it is perfectly acceptable for the data, produced by an experiment, to refute the original hypothesis. The hypothesis should only be stated in one sentence.

## EXPERIMENTATION

Stating the hypothesis in the "if...then" form will guide the investigator in the design of the experiment and in the evaluation of the data it will yield. The investigator should design an experiment which will fulfill the purpose of the study and test the hypothesis.

In the experiment, comparisons are necessary. It is imperative that the student develop adequate controls, that it, keep conditions the same whenever possible. The investigator whould have only variables or experimental changes that relate to the purpose of the experiment. A good experimental design should have a maximum of two variables. If the investigator includes too many variables, the data collected becomes too cumbersome and are difficult to interpret.

As the young scientist experiments, the use of a diary will become very helpful in recording the date and time of his observations. The student should construct data tables that will include the raw data. Graphs, diagrams, and photographs will also help to illustrate the findings of the experiment. It is important for the young scientist to have the reader understand how the problem being investigated was solved. With the use of a carefully though out method of recording data, the student will provide the reader with a simple, orderly, and clear test of the problem.

It is absolutely essential that the student be honest when reporting the findings. If the experimental results do not support the expected results, it is the responsibility of the researcher to report such an outcome in the conclusion.

The experiment designed by the student, with assistance from the instructor, should be divided into four major areas: materials, procedures, observations and data, and analysis and discussion of the data. The four categories are listed and described in the following paragraphs.

I. Materials

What materials will be needed by the student in order to proceed with the experiment? Try to use inexpensive materials. Check to see if local colleges, universities, hospitals, or research institutes will loan specialized equipment not available within the school system.

II. Procedures

The student should provide the reader with an overall outline of the procedures used in the investigation. A detailed description of familiar equipment or experimental techniques in not necessary. If, however, a new type of procedure has been designed and used by the experimenter, it should be described in sufficient detail for the reader to duplicate the investigation. In any case, the student must be neat, concise, and direct when listing the necessary procedures.

## III. Observations and Data

In this section of the report, the experimenter will display the collection of observations (which may be the diary and photographs mentioned earlier), and data. As mentioned previously, the data may be reported in data tables, graphs, or as raw data. It is important that all information be organized neatly and logically.

To support any hypothesis and conclusion to a purpose, the experimenter must show evidence of testing. Therefore, it is vitally important that when the student reports the experimental results, all data are to be organized and recorded in a way that permits easy understanding and interpretation by others. Several steps should be observed in recording data. Each step is listed below.

1. Data should be neatly recorded and effectively organized.
2. Erasures are never permitted on experimental reports. A neat line through an error is sufficient. The correction may be written neatly to the side or above the deletion.
3. Each table in an experimental report should be numbered.
4. Each table should hae an appropriate title.
5. The rows and columns of a table must indicate what has been recorded.

6. Record data in decimal form only.
7. The rules regarding significant figures and scientific notation must be observed.
8. Columns of data should have the decimal points in a vertical line.
9. A zero should always be placed before a decimal point when no other figure occupies that position.
10. Use the metric system of measurement exclusively.
11. Symbols used in data tables and graphs should not be used unless their meaning is perfectly clear to the reader.

## IV. Analysis of Data

In this area of the report, data and observations made during the experiment are analyzed and discussed to give foundation to the experimenter's conclusion. Students are encouraged to use graphs and charts to record the information that results from the investigations. Every chart and graph must be carefully labeled and should have some type of heading or title. Students should be reminded to record things as they happen, even if the results differ from what is being anticipated. If some statistical analysis is needed, students should seek help from the instructor in order to find out exactly what type of statistical test may apply to their situation.

V. Discussion of Data

This area may include the answers to questions the experimenter may have formed during the time the investigation was in progress or perhaps during the time the background research was being conducted. These questions may include the following:

1. How did the experimenter's results compare to results obtained by other closely related investigations?
2. How can the investigation be more fruitful?

VI. Conclusion

Now is the time for the researcher to draw a conclusion. The technique of drawing conclusions from a set of data is rarely as obvious as it may seem at first. No matter how carefully the experimenter may control the conditions of the experiment, variations will occur that can lead to errors in the conclusion. To minimize the possibility of error in the conclusion, the student should conduct several trials during the experiment to be sure that the results are consistent from trial to trial. In the world of research, this is termed redundency, and is very important because it helps to lend credibilibу to the research.

The difference in results between the control group as compared to the experimental group may often times be neglegible, creating doubt in the student's mind about the validity of the data that was collected. This problem may be overcome by making sure the student's techniques of data analysis are scientifically sound.

If the experimenter's data is correct, the student may now accept or reject the original hypothesis. This will be determined by the numbers computed during the statistical analysis of the data, which will be discussed in Unit II of this handbook. In this segment of the research paper, the student may summarize the project, present evidence as to why the original hypothesis was accepted or rejected, and revise the original hypothesis dependent upon the statistical data.

## VII. Application

In this section, the student may state how the experiment conducted may lend itself to practical application. How can the knowledge acquired from the research help improve our culture and way of life? How may it serve to better the lives of others?

## VIII. Recommendations

The researcher should, at this point, reflect back on the project and offer recommendations as to how the experiment or investigation may be improved or revised. The researcher should consider the following questions:

1. What new ideas have come from the project?
2. What aspects of the study should be continued to add to the significance of the research?
3. What new problems have arisen as a direct result of the experimentation?

## IX. Bibliography

There are many different forms that may be used in preparing a bibliography. The instructor should meet with the department chairperson to discuss the different styles available. Whatever the choice, be certain that every teacher follows the same style. As a possible suggestion, it may be wise to check with a local university to find out what style is preferred among the faculty members of that university.

## RECOMMENDED GRADING PROCEDURE

It is recommended that the students research project be graded using the following format.

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## SCIENCE RESEARCH PROJECT

The parts of the research paper will be graded as follows:

| | | |
|---|---|---|
| 1. | Folder | (2 points) |
| 2. | Title Page | (4 points) |
| 3. | Research | (20 points) |
| 4. | Bibliography | (10 points) |
| 5. | Neatness | (9 points) |
| 6. | Originality | (5 points) |

TOTAL POINTS = 50

_____X __2__ = ____%

The experiment and display will be graded as follows:

| | | |
|---|---|---|
| 1. | Abstract | (5 points) |
| 2. | Table of Contents | (3 points) |
| 3. | Purpose | (10 points) |
| 4. | Hypothesis | (10 points) |
| 5. | Materials List | (5 points) |
| 6. | Procedure | (10 points) |
| 7. | Observations | (20 points) |
| 8. | Data Analysis & Stats | (20 points) |
| 9. | Conclusion | (7 points) |
| 10. | Neatness | (5 points) |
| 11. | Acknowledgements | (5 points) |

TOTAL POINTS = 100

## GRADING KEY

90-----100 = A
80------89 = B
70------79 = C
60------69 = D
BELOW 60 = F

# UNIT II

## ELEMENTARY STATISTICAL ANALYSIS

It is particularly important that the instructor involved with the teaching of scientific research be knowledgeable in the area of statistical analysis. I cannot over emphasize the importance of this area of science and mathematics. For this reason, I have included a discussion of what statistics is all about, as well as a segment on how to apply statistics to a given situation. Also included in this section are two widely used statistical tests as well as sample problems that may be used for instructing your students on this most important aspect of science research.

The inherent variability of organisms, coupled with the degree of error normally encounted in most measuring systems, demands the use of some form of data evaluation before valid conclusions can be made or inferences drawn. It is particularly important that students of the biological sciences become familiar with statistical methods of handling data. The following section briefly outlines some of the basic methods used in this form of analysis.

The procedures fall into two groups. The first is concerned with those statistics that define the nature and distribution of the data. The second outlines three procedures that may be used to compare two or more sets of data. A good example is when the students have to compare the results obtained from their experimental groups to those results observed in the control groups. This introduction to statistical methods is not to be regarded as complete, nor is it expected to substitute for formal training in this area. Wherever possible, the instructor should supplement the information given by the use of the references listed in Unit I of this handbook.

## A. Defining the Data

In order to define a sample of data, one must have some knowledge of the central tendencies and degree of dispersion of the data. The statistics usually used for this purpose are the arithmetic mean, the standard deviation, and the confidence interval of the mean.

### 1. Arithmetic Mean

The mean ($\bar{x}$) is computed by summing ($\Sigma$) the individual sample measurements ($x_i$) and dividing by the total number of measurements (N) or (n). The equation for computing the mean in statistics is as follows:

$$\bar{x} = \frac{\Sigma x_i}{N}$$

### 2. Standard Deviation

The mean of a group of data gives little information concerning the distribution of the data about the mean. Obviously, different numerical values can give the same mean value.

For example:

SET 1: 32, 32, 36, 40, 40 $\overline{x} = 36$

SET 2: 2, 18, 24, 36, 100 $\overline{x} = 36$

The means for both sets of figures are identical, however, the variation from the mean in SET 2 is so great as to make the average meaningless. The standard deviation is a measure of data dispersion about the mean. The range covered by the mean plus or minus (+,-) one S.D. includes about 68% of the data upon the basis of which the mean was calculated. The range covered by the mean +,- two standard deviations will include approximately 95% of the data. The calculation of the standard deviation is summarized below.

STEP I

Compute the arithmetical mean ($\overline{x}$) by summing ($\Sigma$) the individual measurements ($x_i$) and dividing by the total number of measurements (n) or (N).

$$\overline{X} = \frac{\Sigma x_i}{N}$$

STEP II

Calculate the deviation from the mean for each measurement.

$$(x_i - \overline{X})$$

### STEP III

Square each of the individual deviations from the mean. This step will eliminate any negative numbers and will allow the researcher to work exclusively with positive numbers. Use the formula below for this procedure.

$$(x_i - \overline{X})^2$$

### STEP IV

Determine the sum of the squared deviations.

$$\sum(x_i - \overline{X})^2$$

### STEP V

You are now ready to calculate the standard deviation (s) or (S.D.) of the sample by using the following formula:

$$s = \sqrt{\frac{(x_i - \overline{X})^2}{N-1}}$$

Having become familiar with the equations involved in calculating the standard deviation for a sample set of data, you are now ready to begin the first exercise. This exercise will serve as a practice problem and will acquaint you with the steps involved in the calculations. Consider the following hypothetical situation on page 45.

## SAMPLE PROBLEM

A homeowner wanted to beautify his landscape in order to increase the property value of his home. He purchased a palm tree from the local nursery and planted it in his front yard. Fertilizing the tree on a regular basis stimulated the growth of the tree immensely. The homeowner took interest in the rate of growth and decided to keep records of the trees monthly progress. The following values represent the trees monthly growth: 50.7 cm, 54.9 cm, 54.3 cm, 44.8 cm, 42.2 cm.. Using the steps listed above, calculate the standard deviation for the recorded data.

The results are as follows:

number of individual measurements (n) or (N) = 5
arithmetical mean ($\overline{X}$) = 246.9/5 = 49.38
degrees of freedom = (n-1) = 4
standard deviation (s) or (S.D.) = 5.67

---

The following five problems may be used as additional practice problems. The answers have been provided in order that you may check your work. These problems are not very lengthy and can serve as practice problems for your students as you introduce the concept of standard deviation.

1. A student measured the molecular mass of a compound five times and obtained the following results (in g/mole). 98.0, 96.5, 97.1, 100.2, 98.3. Calculate the mean and S.D. for the sample data.

ans. X = 98.0 g/mole
s = 1.4 g/mole

2. A student runs three density determinations on an object and obtains the following results: 7.69, 7.59, and 7.62 (g/ml). Calculate the mean and S.D. for the sample data.

ans. $\overline{X}$ = 7.63 g/ml
$s$ = 0.05 g/ml

3. The diameter of a cylindrical object was measured by five students with the following results: 5.42, 6.18, 5.70, 6.01, and 6.23 cm. Calculate the mean and S.D. for the sapmle data.

ans. $\overline{X}$ = 5.93 cm
$s$ = 0.33 cm

4. The following data are twelve scores on a reading test: 19, 28, 25, 30, 16, 12, 21, 18, 17, 29, 23; 20. Calculate the mean and S.D. for the sample data.

ans. $\overline{X}$ = 21.5
$s$ = 5.61

5. The following data are 10 scores on a personality inventory: 110, 102, 90, 100, 112, 115, 95, 110, 112, 95. Calculate the mean and S.D. for the sample data.

ans. $\overline{X}$ = 104.1
$s$ = 8.81

## APPLYING STATISTICS TO SCIENTIFIC RESEARCH

Now that you have mastered the calculations necessary in computing the mean and standard deviation, it is time to move on to a real scientific research experiment. This experiment will allow you to apply what you have learned about standard deviation to find out just what it really means. Consider the following experiment:

A curious student wanted to find out how well mice could travel through a maze after being stressed due to the absence of sleep. After purchasing 10 mice from the local pet shop, the student divided the mice into two equal groups of five. One group was designated the experimental group and the other was called the control group. The mice in the control group were placed in a quiet, dark, and comfortable location.
They were provided with food and water and kept in the dark all evening. The mice in the experimental group were kept in similar surroundings with one exception, they were subjected to loud music all evening long.

The following morning, the student began the experiment by taking one mouse at a time from the experimental group and placing it in a maze. A stop watch was used to time each mouse as it ran through the maze. The same steps were repeated with the mice in the control group. The data from the experiment are as follows:

experimental group: 7, 2, 5, 8, 3 minutes
control group: 3, 6, 8, 2, 2 minutes

Before we analyze the results from this experiment, it is best to organize our data in a chart. The following chart is highly recommended, although you may use another technique that you may be more comfortable with.

| Orig. Data | | Ordered Data | | Data Squared | | Diff. from $\overline{X}$ | | Sq.Diff | |
|---|---|---|---|---|---|---|---|---|---|
| $x_1$ | $x_2$ | $x_1$ | $x_2$ | | | | | | |
| 7 | 3 | 2 | 2 | 4 | 4 | -3 | -2.2 | 9 | 4.84 |
| 2 | 6 | 3 | 2 | 9 | 4 | -2 | -2.2 | 4 | 4.84 |
| 5 | 8 | 5 | 3 | 25 | 9 | 0 | -1.2 | 0 | 1.44 |
| 8 | 2 | 7 | 6 | 49 | 36 | 2 | 1.8 | 4 | 3.24 |
| 3 | 2 | 8 | 8 | 64 | 64 | 3 | 3.8 | 9 | 14.44 |

$x_1$ = represents the experimental group
$x_2$ = represents the control group

**STEP I**:
Compute the arithmetic mean ($\overline{X}$) of the experimental group by summing ( $\sum$ ) the individual measurements ($x_1$) and dividing by the total number of measurements (n) or (N).

arithmetic mean ($\overline{X}$) of $x_1$ = 5 minutes

Complete the same computations for the control group.

arithmetic mean ($\overline{X}$) of $x_2$ = 4.2 minutes

**STEP II**
Refering to the data recorded in the chart, you can now compute the standard deviation (S.D.) for the time trials of the control group. Remember, the equation to use is as follows:

$$s = \sqrt{\frac{(x_i - \overline{X})^2}{N-1}}$$

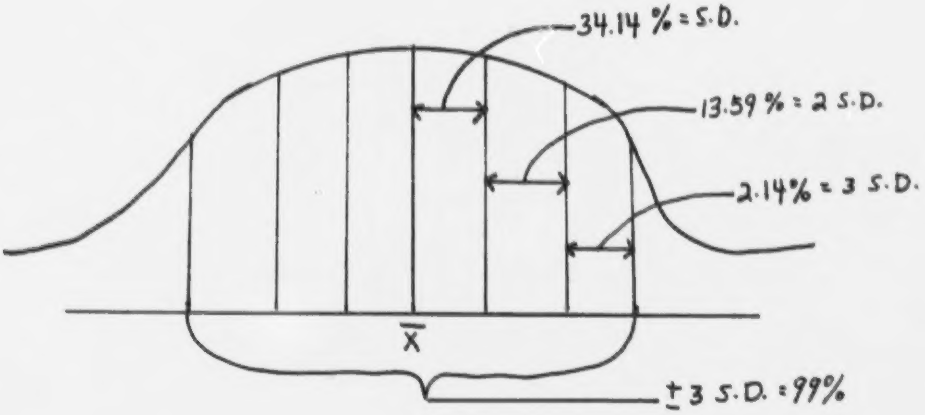
S.D. of $x_2$ = +,- 2.68 or 2.7

Now that you have completed computing the S.D. of the control, it is time to introduce another computation known as the standard of error.(S.E.) The standard of error is computed by dividing the S.D. of the control group by the square root of n-1. The equation is as follows:

$$S.E. = \frac{S.D.}{\sqrt{N-1}}$$

S.E. of control group ($x_2$) = +,- 1.25

It is now time to ask you to rely on your previous experience with the Bell Curve. This is the famous or infamous curve that was drilled into our minds during our formal undergraduate training in the field of education. In education, the Bell Curve is used extensively to plot the results of tests in order to determine the validity of our test results. I have included a diagram of the Bell Curve to serve as a refresher only. A lengthy discussion about the nature of the Bell Curve at this time is not possible. If you feel uncomfortable with your present knowledge of the Curve, I suggest that you do additional reading in your textbooks on educational measurement and evaluation. In any case, the curve is as follows:



## STEP III

It is now time to develop a Bell Curve of your own. At this time, you simple draw the curve on a plain sheet of paper. Do not include any numbers at this time. After drawing the curve, you must then label the middle line (the one drawn below the highest point on the curve) with the mean of the control group, which is 4.2 minutes. You then add and subtract the S.D. from mean you have just plotted. If you recall, the S.D. is always written as +,-. These mathematical signs really mean plus or minus the mean. The next step is to add and subtract two standard deviations from the mean, and then three standard deviations from the mean. Congratulations, you have just calculated the range of the Bell Curve. Your results that have been plotted on the curve should look like this:

-3.9 -1.2 1.5 4.2 6.9 9.6 12.3

One S.D. covers a range between 1.5 to 6.9 .
Two S.D. covers a range between -1.2 to 9.6 .
Three S.D. covers a range between -3.9 to 12.3

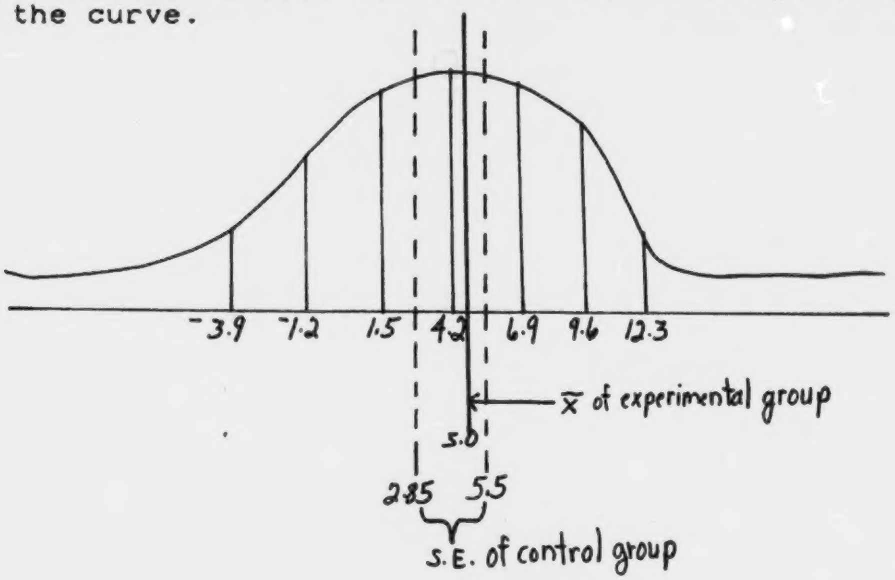
## STEP IV

This step involves plotting the standard of error (S.E.) on the Bell Curve. This is done by adding and subtracting the computed standard of error from the mean of the control group. Once this is accomplished, you should draw two vertically perforated lines on the curve to indicate the range of the standard of error. The range of the standard of error should be as follows:

2.85 4.2 5.5

## STEP V

Finally, you must plot one final value. This value is the mean of the experimental group ($x_1$). You do this by looking at the range beneath the curve and deciding where the mean will fall. You will recall that the mean of the experimental group is 5.0 and will fall somewhere between 4.2 and 5.5. Again, you should draw a vertically perforated line to indicate the mean of the experimental group. To verify your work, I have included a Bell Curve with the values plotted on the curve.



Having completed your computations, along with plotting them on the Bell Curve, you are now ready to draw a conclusion. Before this is done however, a review of the research problem is necessary. Remember, the student wanted to find out if stress would significantly affect the performance of mice as they ran through a maze. Taking a look at the Bell Curve just developed, you will notice that the mean of the experimental group $(x_1)$ falls within the standard of error of the control group ($x_2$). When this happens, it is an indication that there was no appreciable or significant difference between the time trials of the stresses mice as compared to the time trials of the relaxed mice. This is what should be stated in the conclusion. The reasons for this outcome could be numerous. The researcher should also state, in the conclusion, that more data are needed.

When a researcher finds that the mean of the experimental group falls outside the standard of error of the control group, a significant difference should be noted. In other words, there is a significant or substantial difference in the data acquired from the experimental group as compared to the data acquired from the control group. When this happens, additional statistical analysis of the data is necessary. The statistical test of choice, and one that I have included in this handbook, is called the t-Test or student-t.

## t-Test

The t-Test is a statistical technique for determining the probability that the null hypothesis ($H_o$) concerning the means of two samples should be accepted or rejected. The larger the value of t, the greater the probability that the samples represent two different populations. A small value of t increases the probability that the two samples are from the same population.

The formula for the t-Test is

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\dfrac{S_1^2 + S_2^2}{n}}} \quad \text{or} \quad t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\left(\dfrac{S_1^2 + S_2^2}{n_1 + n_2 - 2}\right)\left(\dfrac{1}{n_1} + \dfrac{1}{n_2}\right)}}$$

$\overline{X}_1$ = mean of experimental group (group 1)

$\overline{X}_2$ = mean of control group (group 2)

$s^2$ = variance of sample 1 (group 1)

$s^2$ = variance of sample 2 (group 2)

n or N = number of measurements or data points

Variance ($s^2$) is a measure of the degree that measurements (data points) vary from the mean. To calculate the variance, you must first calculate the mean ($\overline{x}$) of the control group (group 2) and then compare each data point of the control group to that mean. This is done by subtracting the mean from each measurement and then squaring the difference. This sum of the squared differences (deviations) is divided by n-1 or N-1, where n is the total number of measurements. When this is accomplished, you must repeat the entire process with the experimental group. In essence, all you have to do is construct a data table as illustrated in the previous section of this handbook. All the data that you will need can then be extracted from the table.

When working with the variance formula shown below, you may have to alter the demoninator of n. When a sample size of less than 30 is used in an experiment, N-1 should be used instead of n. This is done because a better estimate of the population variance is obtained by assuming that one sample (data point) is on or near the mean. With larger samples (>30), n can be used as it appears in the equation. The formula for variance is:

$$s^2 = \sum \frac{(X_1 - \bar{X})^2}{n-1} \quad \text{or} \quad \sigma = \frac{SS}{n-1}$$

When a researcher conducts an experiment in which the experimental data points are different in number as compared to the control data points, then a slightly different t-Test formula must be used. The formula then becomes as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{S_1^2 + S_2^2}{n_1 + n_2 - 2}\right)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

## SAMPLE PROBLEM #1 (for t-Test)

The difference in food consumption between two groups of mice was monitored daily for one week. The first group consisting of ten mice was placed in a stress-free environment. The other ten mice were placed in identical conditions with the exception of being surrounded by five cats. The results are listed in the table below:

TOTAL FOOD CONSUMPTION OF MICE

| | GRAMS OF FOOD CONSUMED DAILY | |
|---|---|---|
| READINGS | GROUP I (stress free) | GROUP II (stressed) |
| Monday | 38 grams | 47 grams |
| Tuesday | 41 grams | 45 grams |
| Wednesday | 38 grams | 45 grams |
| Thursday | 40 grams | 40 grams |
| Friday | 38 grams | 46 grams |
| Saturday | 42 grams | 44 grams |
| Sunday | 43 grams | 41 grams |
| TOTAL = | 280 grams | 308 grams |
| MEAN ($\bar{X}$) | 40 grams | 44 grams |

In solving this problem, you simply develop a data table as explained earlier and compare the mean of the experimental group (group II) to the mean of the control group (group I). This is accomplished by plotting the results on the Bell

Curve and determining whether or not the mean of the experimental group falls within or outside of the standard of error of the control group. The results should be as follows:

| DEVIATION FROM MEAN $(x_i - \bar{X})$ | | SQUARE OF DEVIATION FROM MEAN $(x_i - \bar{X})^2$ | |
|---|---|---|---|
| GROUP I | GROUP II | GROUP I | GROUP II |
| 2 | 3 | 4 | 9 |
| 1 | 1 | 1 | 1 |
| 2 | 1 | 4 | 1 |
| 0 | 4 | 0 | 16 |
| 2 | 2 | 4 | 4 |
| 2 | 0 | 4 | 0 |
| 3 | 3 | 9 | 9 |
| | | $\sum(x_i - \bar{X})^2 = 26$ | $\sum(x_i - \bar{X})^2 = 40$ |

THE TWO HYPOTHESES FOR THE EXPERIMENT ARE:

$H_o$ = There is no significant difference between the food consumption of groups I and II.

$H_1$ = There will be a significant difference between the food consumption of group I and group II at the .05 probability level, due to stress.

Having plotted the two means on the Bell Curve, you would see that the mean of the experimental group (group I) does fall outside the standard of error of the control group (group II). This indicates that there is enough of a difference to warrent a student-t or t-Test. The results of the t-Test are listed on page 58.

$$t = \frac{40 - 44}{\sqrt{\frac{4.33 + 6.66}{7}}} = \frac{4}{\sqrt{\frac{11}{7}}} = \frac{4}{1.25} = 3.2$$

Referring to the Distribution of t probability table (page 59), it is evident that with 6 degrees of freedom (d.f.) in this problem at the .05 probability level, the value of t is 2.447. Our computed t value of 3.2 exceeds that value, enabling the researcher to reject the null hypothesis ($H_o$). We therefore conclude that the food consumption between the two groups of mice was significant and that we are 95% certain that the mice used in our experiment come from the same population of mice.

# t-Test Probability Table

## SIGNIFICANCE LIMITS OF STUDENT'S t-DISTRIBUTION

| (n) degrees of freedom | Confidence levels | | |
|---|---|---|---|
| | 0.10 | 0.05 | 0.01 |
| 1 | 6.314 | 12.706 | 63.657 |
| 2 | 2.920 | 4.3.3 | 9.925 |
| 3 | 2.353 | 3.182 | 5.841 |
| 4 | 2.132 | 2.776 | 4.604 |
| 5 | 2.015 | 2.571 | 4.031 |
| 6 | 1.943 | 2.447 | 3.707 |
| 7 | 1.895 | 2.365 | 3.499 |
| 8 | 1.860 | 2.306 | 3.355 |
| 9 | 1.833 | 2.262 | 3.250 |
| 10 | 1.812 | 2.228 | 3.169 |
| 11 | 1.796 | 2.201 | 3.106 |
| 12 | 1.782 | 2.179 | 3.055 |
| 13 | 1.771 | 2.160 | 3.012 |
| 14 | 1.761 | 2.145 | 2.977 |
| 15 | 1.753 | 2.131 | 2.947 |
| 16 | 1.746 | 2.120 | 2.921 |
| 17 | 1.740 | 2.110 | 2.898 |
| 18 | 1.734 | 2.101 | 2.878 |
| 19 | 1.729 | 2.093 | 2.861 |
| 20 | 1.725 | 2.086 | 2.845 |
| 21 | 1.721 | 2.080 | 2.831 |
| 22 | 1.717 | 2.074 | 2.819 |
| 23 | 1.714 | 2.069 | 2.807 |
| 24 | 1.711 | 2.064 | 2.797 |
| 25 | 1.708 | 2.060 | 2.787 |
| 26 | 1.706 | 2.056 | 2.779 |
| 27 | 1.703 | 2.052 | 2.771 |
| 28 | 1.701 | 2.048 | 2.763 |
| 29 | 1.699 | 2.045 | 2.756 |
| 30 | 1.697 | 2.042 | 2.750 |
| 40 | 1.684 | 2.021 | 2.704 |
| 60 | 1.671 | 2.000 | 2.660 |
| 120 | 1.658 | 1.980 | 2.612 |
| x | 1.645 | 1.960 | 2.576 |

Adapted from Table III of Fisher and Yates, Statistical Tables for Biological, Agricultural, and Medical Research, Oliver & Boyd, Edinburgh.

**SAMPLE PROBLEM #2** (for t-Test)

For the following data:

1. Form a null hypothesis ($H_o$)
2. Form an experimental hypothesis ($H_1$)
3. Perform the t-Test to determine if you should accept or reject the null hypothesis.

Twenty six men were given a knee jerk test where the measurements are in terms of degrees of arc. One group was tested immediately after squeezing a hand dynamometer (stressed group $x_1$). The second group consisted of twenty-nine men who did not squeeze the hand dynamometer (relaxed group $x_2$, also the control group).

The constructed data table is located on page 61.

## KNEE JERK TEST RESULTS

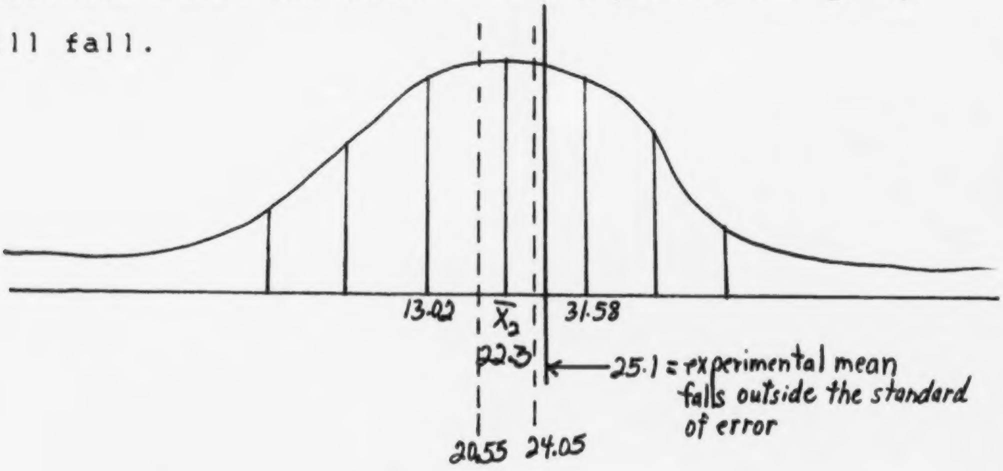
| ORDERED DATA |  | DATA SQUARED |  | DIFF. FROM MEAN |  | SQUARE OF DIFFERENCES |  |
|---|---|---|---|---|---|---|---|
| $X_1$ | $X_2$ |  |  |  |  |  |  |
| 8 | 1 | 64 | 1 | -17.1 | -21.3 | 292.41 | 453.69 |
| 15 | 4 | 225 | 16 | -10.1 | -18.3 | 102.00 | 334.89 |
| 16 | 7 | 256 | 49 | - 9.1 | -15.3 | 82.81 | 234.09 |
| 18 | 11 | 324 | 121 | - 7.1 | -11.3 | 50.41 | 127.69 |
| 18 | 13 | 324 | 169 | - 7.1 | - 9.3 | 50.41 | 86.49 |
| 19 | 14 | 361 | 196 | - 6.1 | - 8.3 | 37.21 | 68.89 |
| 19 | 14 | 361 | 196 | - 6.1 | - 8.3 | 37.21 | 68.89 |
| 19 | 18 | 361 | 324 | - 6.1 | - 4.3 | 37.21 | 18.49 |
| 21 | 19 | 441 | 361 | - 4.1 | - 3.3 | 16.81 | 10.89 |
| 22 | 19 | 484 | 361 | - 3.1 | - 3.3 | 9.61 | 10.89 |
| 22 | 19 | 484 | 361 | - 3.1 | - 3.3 | 9.61 | 10.89 |
| 26 | 20 | 676 | 400 | 0.9 | - 2.3 | 0.81 | 5.29 |
| 26 | 21 | 676 | 441 | 0.9 | - 1.3 | 0.81 | 1.69 |
| 26 | 23 | 676 | 529 | 0.9 | 0.7 | 0.81 | .49 |
| 26 | 24 | 676 | 576 | 0.9 | 1.7 | 0.81 | 2.89 |
| 28 | 25 | 784 | 625 | 2.9 | 2.7 | 8.41 | 7.29 |
| 29 | 26 | 841 | 676 | 3.9 | 3.7 | 15.21 | 13.69 |
| 30 | 26 | 900 | 676 | 4.9 | 3.7 | 24.01 | 13.69 |
| 30 | 27 | 900 | 729 | 4.9 | 4.7 | 24.01 | 22.09 |
| 30 | 29 | 900 | 841 | 4.9 | 6.7 | 24.01 | 44.89 |
| 31 | 29 | 961 | 841 | 5.9 | 6.7 | 34.81 | 44.89 |
| 33 | 29 | 1089 | 841 | 7.9 | 6.7 | 62.41 | 44.89 |
| 34 | 30 | 1156 | 900 | 8.9 | 7.7 | 79.21 | 59.29 |
| 35 | 30 | 1225 | 900 | 9.9 | 7.7 | 98.01 | 59.29 |
| 36 | 31 | 1296 | 961 | 10.9 | 8.7 | 118.81 | 75.69 |
| 36 | 31 | 1296 | 961 | 10.9 | 8.7 | 118.81 | 75.69 |
|  | 34 |  | 1156 |  | 11.7 |  | 136.89 |
|  | 35 |  | 1225 |  | 12.7 |  | 161.29 |
|  | 37 |  | 1369 |  | 14.7 |  | 216.09 |
| 653 | 646 | 17,737 | 16,802 |  |  | 1336.65 | 2411.81 |

MEAN $X_1$ = 25.1
MEAN $X_2$ = 22.3
d.f. = $n_1 + n_2$ or 26 + 29 - 2 = 53.0 This formula is used whenever the two groups being compared have a different number of data points.

THE TWO HYPOTHESES ARE AS FOLLOWS:

1. $H_0$ = There will be no significant difference between the reflexes of the stressed men as compared to the relaxed men.
2. $H_1$ = There will be a significant difference between the reflexes of the stressed men as compared to the relaxed men.

Before the t-Test is applied in our analysis of the data, we must first calculate the standard of error of the control group to determine whether or not a t-Test is appropriate. The results of the experiment are plotted on the Bell Curve to determine where the mean of the experimental group will fall.



As you can see from the Curve, the mean of the experimental group does fall outside of the standard of error of the control group.

This means that there is a significant difference between the mean of the experimental group as compared to the mean of the control group. Therefore, a t-Test is appropriate to conduct at this time.

The computed value of t is 1.27. It must now be compared to the value from the t-distribution table. Since our experiment is biological in nature, it is customary, as the researcher, to choose the .05 probability probability (significance) level. The degree of freedom in this experiment is 53, but the t-distribution table does not include this number. The alternative is to choose the closest number which will be the number 60. Following across the row, you will find that the value for 60 degrees of freedom under the .05 probability level is 2.000.

In order to decide whether or not to accept or reject the null hypothesis, a comparison of the computed value of t (1.27) must be made with the t-distribution value (2.000). Since the computed value of t is less than the t-distribution value, the null hypothesis is accepted. Based on this information, the researcher can now develop a conclusion for the experiment.

## Chi-square ($X^2$)

The Chi-square test is most often used to evaluate differences between experimental (observed) data and hypothetical (expected) data. This type of statistical test may be used with two or more samples. It is often referred to as the "goodness of fit" test. That is, how well does a researchers observations coincide with the predicted outcome. The formula used in determining Chi-square is as follows:

$$X^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

$f_o$ = frequency of the observed datum

$f_e$ = frequency of the expected datum

As in the t-Test, the researcher must calculate the degrees of freedom (d.f.) in the experiment. The formula for this calculation is as follows:

d.f. = K - 1
K = number of attributes (data points)

## Chi-square Distribution Table

| d.f. | probability level (p) | | | |
|---|---|---|---|---|
| | .10 | .05 | .01 | .001 |
| 1 | 2.706 | 3.841 | 6.635 | 10.827 |
| 2 | 4.605 | 5.991 | 9.210 | 13.815 |
| 3 | 6.251 | 7.815 | 11.345 | 16.266 |
| 4 | 7.779 | 9.488 | 13.277 | 18.467 |
| 5 | 9.236 | 11.070 | 15.086 | 20.515 |
| 6 | 10.645 | 12.592 | 16.812 | 22.457 |
| 7 | 12.017 | 14.067 | 18.475 | 24.332 |
| 8 | 13.362 | 15.507 | 20.090 | 26.125 |
| 9 | 14.684 | 16.919 | 21.666 | 27.877 |
| 10 | 15.987 | 18.307 | 23.209 | 29.588 |
| 11 | 17.275 | 19.675 | 24.725 | 31.264 |
| 12 | 18.549 | 21.026 | 26.217 | 32.909 |
| 13 | 19.812 | 22.362 | 27.688 | 34.528 |
| 14 | 21.064 | 23.685 | 29.141 | 36.123 |
| 15 | 22.307 | 24.996 | 30.578 | 37.697 |
| 16 | 23.542 | 26.296 | 32.000 | 39.252 |
| 17 | 24.769 | 27.587 | 33.409 | 40.790 |
| 18 | 25.989 | 28.869 | 34.805 | 42.312 |
| 19 | 27.204 | 30.144 | 36.191 | 43.820 |
| 20 | 28.412 | 31.410 | 37.566 | 45.315 |

This is a modified table of $X^2$ values. It is taken from Table IV of Fisher and Yates: **Statistical Tables for Biological, Agricultural and Medical Research**, published by Oliver & Boyd, Edinburgh.

**SAMPLE PROBLEM #1** (for Chi-square test)

The launch of the Hubble Space Telescope was broadcast simultaneously by the nations three major television networks (ABC, CBS, NBC). If there were no differences in the broadcasts, we would expect the same number of people to be watching each of the three networks. After the launch was successfully executed, 900 people were randomly surveyed to find out which television network they had watched for coverage of the launch. the following results were obtained:

**TELEVISION NETWORKS**

| | ABC | CBS | NBC |
|---|---|---|---|
| Observed | 310 | 340 | 250 |
| Expected | 300 | 300 | 300 |

Having obtained the data, the next step is to formulate both the null hypothesis and the experimental (research) hypothesis.

null hypothesis ($H_o$): There will be no significant difference among the number of people watching the Hubble launch broadcast on the three major networks.

experimental hypothesis ($H_1$): It is believed that significantly more people would watch the Hubble launch broadcast on one station than on either of the other two stations.

In order to determine whether the observed frequencies are significantly different from the expected frequencies, the following $X^2$ formula is applied:

$$X^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

$$X^2 = \frac{(310-300)^2}{300} + \frac{(340-300)^2}{300} + \frac{(250-300)^2}{300}$$

$$X^2 = \frac{10^2}{300} + \frac{50^2}{300} + \frac{40^2}{300}$$

$$X^2 = \frac{100}{300} + \frac{2500}{300} + \frac{1600}{300}$$

$$X^2 = 0.33 + 8.33 + 5.33$$

$$X^2 = 13.99$$

With three attributes (data points), ABC, CBS, and NBC, we have two degrees of freedom (3 - 1). Referring to the Chi-square Distribution Table, we find that with two degrees of freedom (d.f.) and a $X^2$ value of 13.815 under the .001 probability level (p), our computed value of $X^2$ (13.99) exceeds that level. Therefore, we reject the null hypothesis and rule out chance as a factor in our research. Had the computed $X^2$ value been less than the probability level, we would have accepted the null hypothesis ($H_o$).

---

## SAMPLE PROBLEM #2 (for Chi-square Test)

Horse racing fans often maintain that in a race around a circular track, significant advantages accrue to the horses in certain post positions. Any horse's post position is his assigned post in the starting line up. Position 1 is closest to the rail on the inside of the track; position 8 is on the outside, farthest from the rail in an 8 horse race. The following data was obtained for the first month of racing at *Rockingham Park*. The data includes a total of 144 races:

**POST POSITION**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| observed wins | 29 | 19 | 18 | 25 | 17 | 10 | 15 | 11 |
| expected wins | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

1. Form the null hypothesis ($H_o$)
2. Form the experimental hypothesis ($H_1$)
3. Test the significance of the data by means of the Chi-square Test.

The problem is solved in the following manner:

$$X^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

$$X^2 = \frac{(29-18)^2}{18} \quad \frac{(19-18)^2}{18} \quad \frac{(18-18)^2}{18} \quad \frac{(25-18)^2}{18} \quad \frac{(17-18)^2}{18} \quad \frac{(10-18)^2}{18} \frac{(15-18)^2}{18} \quad \frac{(11-18)^2}{18}$$

$$X^2 = \frac{121}{18} + \frac{1}{18} + \frac{0}{0} + \frac{49}{18} + \frac{1}{18} + \frac{64}{18} + \frac{9}{18} + \frac{49}{18}$$

$$X^2 = \frac{294}{18} = 16.3$$

degrees of freedom (d.f.) = 7
$X^2$ distribution table = Using the .05 (p) level, the value would be 14.067.

CONCLUSION:

For a significance level of .05, the computed value of $X^2$ (16.3) would be greater than the $X^2$ distribution value (14.067). This would indicate to the researcher that the null hypothesis should be rejected. However, had the researcher used the probability level of .01, the $X^2$ distribution value of 18.475 would be greater than the computed value of $X^2$ and the researcher would then accept the null hypothesis ($H_o$).

---

**SAMPLE PROBLEM #3** (for Chi-square Test)

A public opinion polling team in a small town was interested in the type of sporting events that adults in the age bracket 20 - 50 years prefer to watch on television. A random sample of 120 people in this age bracket was selected and asked, "Given your preference, would you prefer to watch baseball, basketball, or football on your television set at home?" The following is a listing of the data.

**PREFERRED SPORT**

| | Baseball | Basketball | Football | Total |
|---|---|---|---|---|
| observed frequency | 39 | 25 | 56 | 120 |
| expected frequency | 40 | 40 | 40 | |

1. Form the null hypothesis ($H_o$)
2. Form the experimental hypothesis ($H_1$)
3. Test the significance of the data by means of the Chi-square Test

The problem is solved in the following manner:

$$X^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

$$X^2 = \underline{(39-40)^2} + \underline{(25-40)^2} + \underline{(56-40)^2}$$

$$X^2 = \frac{1}{40} + \frac{225}{40} + \frac{256}{40} = \frac{482}{40}$$

$$X^2 = 12.05$$

degrees of freedom (d.f.) = 2
$X^2$ distribution table = Using the .05 (p) level, the value would be 5.991.

**CONCLUSION**:

The deviation of the observed frequencies from the expected frequencies is significant and the null hypothesis should be rejected.

---

# UNIT III

# SAFETY/SECURITY GUIDELINES
# FOR
# SCIENCE LABORATORIES

1. Maintain a wholesome, businesslike atitude at all times. For the safety of the whole class, unauthorized experiments are prohibited.

2. Report even minor injuries to your instructor at once.

3. If corrosive liquids touch the skin or clothes, flood with water. Consult your instructor.

4. Do not point your test tube at your neighbor or yourself when heating substances. A suddenly formed bubble of vapor may eject the contents violently (called "bumping").

5. Do not hold your face directly over a container when noting the odor. Instead, fan a little of the vapor toward your nostrils by sweeping your hand over the top of the container.

6. NEVER taste a chemical or solution unless directed to do so. (Poisonous) substances are not always so labeled in the lab.

7. Beware of hot glass or other materials--it looks cool long before it may be handled safely.

8. Neutralize spilled acids, bases, or other reagents by flooding with water.

9. To insert glass tubing (including thermometers, thistle tubes, etc.) through a rubber stopper, first lubricate the tube and stopper with water (unless moisture must be avoided). Hold the tubing with a cloth near the end to be inserted, and insert with a twisting motion. (If you twist a thistle tube by the "thistle" end, it is easily broken.)

10. Wear a laboratory apron, coat or old clothes to protect your clothes from corrosive chemicals. (It's cheaper!)

11. Maintain an orderly, clean laboratory desk. Invert glassware over a paper towel to dry.

12. Wash and wipe the desk top at the close of the period.

13. Discard solids into the waste crocks. Never throw matches, litmus, or any insoluble solids into the sink. Wash down liquids into the sink with much water. Pathogenic materials will be collected and sterilized by the laboratory staff before disposal.

14. Leave reagent bottles at the side shelves. Bring test tubes or beakers to the shelf for transferring chemicals and carrying them to your desk.

15. Read the label twice before taking anything from a bottle. All materials should be properly labeled for identification by other students and/or instructors.

16. Avoid using excessive amounts of reagent--2 or 3 ml. is usually ample for test tube reagents.

17. NEVER return unused chemicals to the stock bottle. You may make a mistake from which other student's experiments will suffer.

18. Do not insert your own pipets or medicine droppers into the reagent bottles. Avoid contamination of the stock solution by pouring the solution from the bottle.

19. NEVER lay a stopper of a reagent bottle on the workbench surface. Impurities may be picked up and thus contaminate the solution when the stopper is returned.

20. Avoid heating any apparatus too suddenly; apply the heat slowly at first. Test tubes may break if they are heated above the liquid level and liquid is then splashed over the hot glass.

21. Shoes must be worn in the laboratory at all times.

22. The NO SMOKING regulation is constantly enforced.

23. Long hair, loose clothing, and jewelry must be secured to that they will not come in contact with flame, reagents, and instruments.

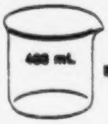
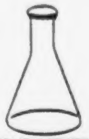
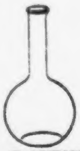
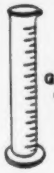
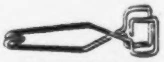
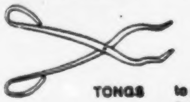
24. Students are advised that no laboratory instruments or other items of equipment are to be touched or used without the instructor's approval.

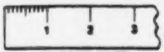
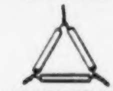
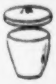
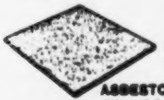
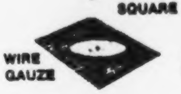
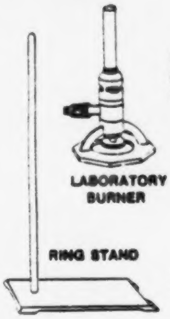
25. Strict adherence to oral and written instructions is required at all times!!!!

Permission to reproduce these safety guidelines has been granted by the following author. However, this listing must accompany all reproductions.

Laboratory Workbook for Introductory Cell Biology
John A. Jones
Miami-Dade Community College
Paladin House, Publishers
Geneva, Illinois 60134

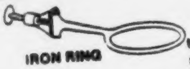
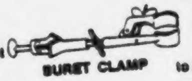
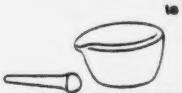
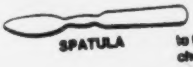
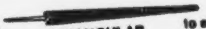
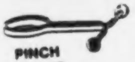
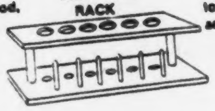
# LIST OF APPARATUS FOR STUDENT USE

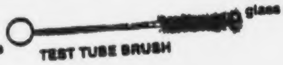
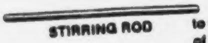
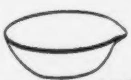
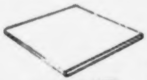
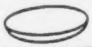
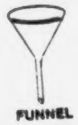
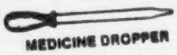
| DESCRIPTION | APPARATUS | USE |
|---|---|---|
| glass<br>common sizes<br>100 mL<br>250 mL<br>400 mL<br>marked on the beaker |  BEAKER | as a container, like a cup<br>may be heated |
| glass<br>common sizes<br>125 mL<br>250 mL<br>500 mL<br>marked on the flask |  ERLENMEYER FLASK  FLORENCE FLASK | may be heated |
| glass<br>marked with a milliliter (mL) scale<br>size — divisions<br>50 mL — 1.0 mL<br>35 mL — 0.2 or 0.5 mL<br>10 mL — 0.1 mL |  GRADUATED CYLINDER | to measure volume |
| glass<br>several sizes | TEST TUBE | many uses<br>can be heated |
| metal<br>clamp with a spring handle |  TEST TUBE CLAMP | to hold a test tube |
| metal |  TONGS | to pick up and hold apparatus |

| DESCRIPTION | APPARATUS | USE |
|---|---|---|
| 10 centimeter (cm) ruler, plastic divided into centimeter and millimeter (mm) divisions |  10 CM RULER | to measure length |
| triangular wire frame with clay material coverings |  PIPESTEM TRIANGLE | to support the crucible |
| small porcelain dish with cover |  CRUCIBLE AND COVER | to heat small amounts of solid material at high temperature |
| hardened asbestos |  ASBESTOS SQUARE | to place under hot apparatus |
| wire screen asbestos center | WIRE GAUZE  | to spread the heat of a flame |
| metal heating device connected to gas outlet with rubber tubing |  LABORATORY BURNER | to heat chemicals in beakers or test tubes |
| metal rod upright heavy base | RING STAND | a support with many uses |

Permission to reproduce the LIST OF APPARATUS FOR STUDENT USE has been granted by the following publisher. The following reference must accompany all reproductions.

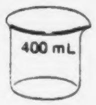
Laboratory Experiments in Action Chemistry
by Bolton, et al.
Holt, Rinehart, and Winston
New York, 1979 pages 4, 5, and 8.

| DESCRIPTION | APPARATUS | USE |
|---|---|---|
| iron ring with<br>screw fastener<br>several sizes |  IRON RING | to fasten to the ring stand as a support for apparatus |
| metal clamp with<br>1. screw fastener<br>2. swivel and lock nut<br>3. adjusting screw<br>4. curved clamp |  BURET CLAMP | to hold apparatus<br>may be fastened to the ring stand |
| heavy porcelain dish with grinder |  MORTAR AND PESTLE | to grind chemicals to a powder |
| may be of metal or porcelain |  SPATULA | to transfer solid chemicals in weighing |
| metal file with three cutting edges |  TRIANGULAR FILE | to scratch glass<br>to file |
| short length of rubber tubing | RUBBER CONNECTOR | to connect parts of apparatus |
| metal clamp with finger grips |  PINCH CLAMP | to clamp a rubber connector |
| rack; may be wood, metal or plastic | TEST TUBE RACK  | to hold test tubes in an upright position |

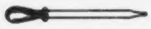
| DESCRIPTION | APPARATUS | USE |
|---|---|---|
| brush with wire handle |  TEST TUBE BRUSH | to scrub glass apparatus |
| glass rod |  STIRRING ROD | to stir combinations of materials<br>to use in pouring liquids |
| porcelain dish |  EVAPORATING DISH | as a container for small amounts of liquid being evaporated |
| thick glass |  GLASS PLATE | many uses (should not be heated) |
| curved glass |  WATCH GLASS | may be used as a beaker cover<br>may be used in evaporating very small amounts of liquid |
| glass or plastic |  FUNNEL | to hold a filter paper<br>may be used in pouring |
| glass tip with rubber bulb |  MEDICINE DROPPER | to transfer small amounts of liquid |
| metal | FORCEPS | to pick up or hold small objects |

## A REVIEW OF LABORATORY KNOW-HOW

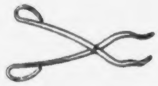
1. What apparatus or glassware is used
   (a) to pick up and hold apparatus
   (b) to scrub glassware
   (c) as a cover for a beaker
   (d) to transfer solid chemicals in weighing
   (e) as a container for small amounts of liquid being evaporated
   (f) to grind chemicals to a powder
   (g) to measure a volume of a liquid
   (h) to measure length
   (i) to fasten to the ring stand as a support upon which to set apparatus
   (j) to heat small amounts of solids at high temperatures
2. What is the name of each of the following?
   (Write your answer on the line under the diagram.)



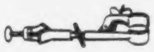
a.



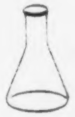
f.



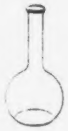
k.



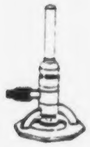
g.



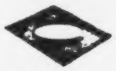
j.



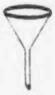
l.



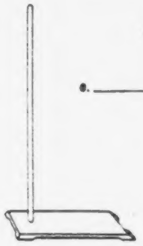
b.



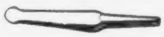
h.



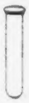
c.



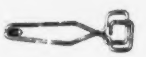
i.



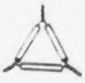
e.



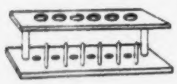
m.



o.



n.



d.

# REVIEW OF METRIC UNITS

BASIC UNITS

1. The **meter** is the unit of length and distance.
   A meter stick is 3.37 inches longer than an ordinary yard stick

2. The liter is the unit of volume.
   A liter cylinder is slightly larger than a quart measure.

3. The **gram** is the unit of mass and weight.
   It takes 454 grams to equal 1 pound.

PREFIXES

The prefixes used have the same value in length, volume, and mass.

1. kilo- = 1000 times the basic unit

2. centi- = 1/100 (0.01) of the basic unit
   100 centi-s make one unit

3. milli- = 1/1000 (0.001) of the bsic unit
   1000 milli-s make one unit
   10 milli-s make one centi-

Note: Values are in steps of 10, that is, 10, 100, 1000. Changes can be made from one level to another by moving the decimal place. **Example:** 1 milli- = 0.1 centi-
**Example** 1 liter = 1000 milliliters.

Note: The following chart has been reproduced with permission from the author and may Xeroxed as necessary.

| Measurement | Symbol | Value |
|---|---|---|
| | **LENGTH and DISTANCE** | |
| *kilometer | km | 1000.00 meters |
| meter | m | 1.00 meter – unit of length |
| centimeter | cm | 0.01 meter |
| millimeter | mm | 0.001 meter |
| *Added for completeness | | |
| | **VOLUME (CAPACITY)** | |
| kiloliter | kL | 1000.00 liters |
| liter | L | 1.00 liter – unit of volume |
| milliliter | mL | 0.001 liter |
| milliliter | mL | 1.00 cubic centimeter (cm³) |
| | **MASS AND WEIGHT** | |
| kilogram | kg | 1000.00 grams |
| gram | g | 1.00 gram – unit of mass |
| milligram | mg | 0.001 gram |

## CALCULATIONS

There are three steps of ten each from kilo- to the basic unit of one; and three more steps of ten each from the basic unit of one to milli-. This makes six steps of ten each from kilO- to milli-. For each step of ten, move the decimal point one place.

Move the decimal point to the right when going from kilo- toward milli-.

Move the decimal point to the left when going from milli- toward kilo-.

## STEPS OF TEN

| | |
|---|---|
| kilo- | 1000.00 |
| | 100.00 |
| | 10.00 |
| basic unit | 1.00 |
| deci- | 0.10 |
| centi- | 1.01 |
| milli- | 0.001 |

# WORKSHEET ON METRIC CONVERSIONS

Make the changes as indicated.

1. 2 kg to ______g to ______mg

2. 400 mL to ______L

3. 200 mm to ______cm to ______m

4. 2 L to ______mL

5. 250 mg to ______g to ______kg

6. 1/4 L to ______mL

7. 1/5 L to ______mL

8. 1/2 L to ______mL

9. 568 g to ______kg to ______mg

10. 625 mm to ______cm to ______m

11. 68 mL to ______L

12. 870 mL to ______L

13. 0.5 mL to ______L

14. 1.2 L to ______mL

15. 0.95 L to ______mL

16. 54g to ______mg

17. 925 mg to ______g

18. 25 L to ______mL

19. 15 mm to ______cm

20. 15 mm to ______m

### SIGNIFICANT FIGURES IN CALCULATIONS: ROUNDING OFF

The final answer of a calculation made on a modern calculator usually has more digits than any of the numbers used in the calculation. We must round off the calculated number, that is, drop nonsignificant digits so that the proper number of significant figures is reported. The process of determining the correct number of significant figures depends on the kind of calculation.

1 When the figure immediately following the last digit to be retained in a number is less than 5, the last digit is retained unchanged. If 6.4362 is to be rounded off to four significant figures, it becomes 6.436.
2 When the figure immediately following the last digit to be retained is greater than 5, increase the last retained figure by 1. If 6.4366 is to be rounded off to four significant figures, it becomes 6.437.
3 When the figure immediately following the last digit to be retained is 5 and there are no other figures beyond the 5, or there are only zeros beyond the 5, the last digit to be retained is increased by 1 if it is odd and left unchanged if it is even. Thus, 2.135 or 2.1350 becomes 2.14 if three figures are to be retained.
4 When the figure immediately following the last digit to be retained is 5 and there are figures other than zero beyond the 5, the last figure to be retained is increased by 1, whether it is odd or even. Thus, 2.1453 becomes 2.15 when only three figures are to be retained.

The rules for determining the proper number of significant figures in a calculated number are as follows:

1 Addition and subtraction: The final answer obtained when adding or subtracting numbers must be rounded off so that it has the same number of significant figures to the right of the decimal as the number in the calculation that has the fewest digits to the right of the decimal.
2 Multiplication and division: The rule for rounding off the final calculated answer when multiplying or dividing numbers is to round off the final calculated answer so that it has the same number of significant figures as the least certain number (the one with fewest significant figures) in the calculation. A little caution must be used when applying this rule. For example, to divide 120 by 95, you might be tempted to report the final answer to two significant figures because 95 appears to be the least certain number. Yet 95 has almost three significant figures; there is very little difference in error between 1 in 95 and 1 in 101. Thus, in this case it makes more sense to round off the final answer to three significant figures. Use common sense in problems when a number is close in magnitude to 100, 1000, 10,000, and so on.
3 Exact measured values or defined numbers are not used in determining the number of significant figures in a final answer. If you use the equation $A = 4\pi r^2$ to measure the surface area of a sphere, the number 4 is considered to have an infinite number of significant figures and is therefore not used in determining the relative certainty of the calculated area.

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Student's Guide to Brown and Lemay Chemistry
The Central Science, 2nd ed. by Hill
Prentice-Hall, Inc., Englewood Cliffs, N.J. 07632, p. 5.

# REVIEW SHEET FOR SIGNIFICANT FIGURES

1. How many significant figures are given in each of the following numbers?

(a) 2.205 ans. 4
(b) 0.0353 ans. 3
(c) 1.0080 ans. 5
(d) 14.0 ans. 3
(e) $9.3 \times 10^{7}$ ans. 2
(f) $1.118 \times 10^{-3}$ ans. 4

2. Perform each of the indicated operations and express your answer with the proper number of significant figures.

(a) (18.425) + (7.21) + (5.0)
(b) (4.0) + (0.632) + (0.148)
(c) (562.4) - (16.8)
(d) (34) - (0.2)
(e) (107.87) X ((0.610)
(f) (7.24) X (4.113)
(g) (2.02) X (4.113)
(h) (97.52) / (2.54)
(i) (14.28) / (0.714)
(j) (0.032) / (0.004)

---

a. 30.6
b. 4.8
c. 545.6
d. 34
e. 65.8
f. 62
g. 8.31
h. 38.4
i. 20.0
j. 8

# REVIEW OF EXPONENTIAL NUMBERS

## ADDITION OF EXPONENTIALS

Convert all the numbers to the same power of 10 and add the digit terms of the numbers.

**Example:** $5 \times 10^{-2} + 3 \times 10^{-3}$

$$\begin{array}{r} 50 \times 10^{-3} \\ +3 \times 10^{-3} \\ \hline 53 \times 10^{-3} = 5.3 \times 10^{-2} \end{array} \quad \text{or} \quad \begin{array}{r} 5 \times 10^{-2} \\ +0.3 \times 10^{-2} \\ \hline 5.3 \times 10^{-2} \end{array}$$

## SUBTRACTION OF EXPONENTIALS

Convert all the numbers to the same power of 10 and subtract the digit terms of the numbers.

**Example:** $5 \times 10^{-6} - 4 \times 10^{-7}$

$$\begin{array}{r} 5 \times 10^{-6} \\ -0.4 \times 10^{-6} \\ \hline 4.6 \times 10^{-6} \end{array} \quad \text{or} \quad \begin{array}{r} 50 \times 10^{-7} \\ -4 \times 10^{-7} \\ \hline 46 \times 10^{-7} = 4.6 \times 10^{-6} \end{array}$$

## MULTIPLICATION OF EXPONENTIALS

Multiply the digit terms in the usual way and algebraically add the exponents of the exponential terms (that is, $10^a \times 10^b = 10^{a+b}$).

**Examples**

$(4.2 \times 10^{-8})(2 \times 10^{3}) = 8.4 \times 10^{-5}$

$(4.2 \times 10^{-8})(2 \times 10^{-3}) = 8.4 \times 10^{-11}$

$(4.2 \times 10^{8})(2 \times 10^{-3}) = 8.4 \times 10^{5}$

## DIVISION OF EXPONENTIALS

Divide the digit terms of the numerator by the digit term of the denominator and subtract algebraically the exponents of the exponential terms (that is, $10^a/10^b = 10^{a-b}$).

**Examples**

$$\frac{4.2 \times 10^{-8}}{2 \times 10^{3}} = 2.1 \times 10^{-11}$$

$$\frac{4.2 \times 10^{-8}}{2 \times 10^{-3}} = 2.1 \times 10^{-5}$$

$$\frac{4.2 \times 10^{8}}{2 \times 10^{-3}} = 2.1 \times 10^{11}$$

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Student's Guide to Brown and Lemay Chemistry
The Central Science, 2nd ed. by Hill
Prentice-Hall, Inc., Englewood Cliffs, N.J. 07632, pp. 347-348.

### SQUARING OF EXPONENTIALS

Square the digit term in the usual way and multiply the exponent of the exponential term by 2 (that is, $(10^a)^2 = 10^{2a}$).

**Examples**

$(4 \times 10^{-2})^2 = 16 \times 10^{-4} = 1.6 \times 10^{-3}$

$(5 \times 10^4)^2 = 25 \times 10^8 = 2.5 \times 10^9$

$(1.2 \times 10^3)^2 = 1.44 \times 10^6$

### RAISING AN EXPONENTIAL TO A GENERAL POWER

Raise the digit term to the power in the usual way and multiply the exponent of the exponential term by the power (that is, $(10^a)^b = 10^{ab}$).

**Examples**

$(2 \times 10^{-2})^3 = 8 \times 10^{-6}$

$(1 \times 10^3)^5 = 1 \times 10^{15}$

### EXTRACTION OF SQUARE ROOTS OF EXPONENTIALS

Decrease or increase the exponential term so that the power of 10 is evenly divisible by 2. Extract the square root of the digit term by inspection or by logarithms and divide the exponential term by 2 (that is, $\sqrt{10^a} = 10^{a/2}$).

**Example** Find the square root of $1.6 \times 10^{-7}$.

$1.6 \times 10^{-7} = 16 \times 10^{-8}$

$\sqrt{16 \times 10^{-8}} = \sqrt{16} \times \sqrt{10^{-8}} = 4 \times 10^{-4}$

### COMBINED OPERATIONS

Any combination of the above operations is performed by doing each operation individually and combining the results.

**Example** Solve the equation $(a/2.5 \times 10^{-3}) = (7.4 \times 10^8/3.9 \times 10^{-6})$.

$$a = \frac{(2.5 \times 10^{-3})(7.4 \times 10^8)}{(3.9 \times 10^{-6})} = (2.5 \times 10^{-3})(1.9 \times 10^{14})$$

$$= 4.75 \times 10^{11}$$

Because the operations of multiplication and division are commutative, it makes no difference which we perform first; that is, the order of operations is immaterial:

$$a = \frac{(2.5 \times 10^{-3})(7.4 \times 10^8)}{(3.9 \times 10^{-6})} = \frac{1.85 \times 10^6}{3.9 \times 10^{-6}} = 4.74 \times 10^{11}$$

The difference in these two numbers (4.74 and 4.75) is due to an error in rounding off.

## REVIEW EXERCISES FOR EXPONENTIAL OPERATIONS

1. Express the following in powers of 10.

| | | |
|---|---|---|
| (a) | 32,600 | ans. $3.26 \times 10^{4}$ |
| (b) | 0.831 | ans. $8.31 \times 10^{-1}$ |
| (c) | 46,000,000 | ans. $4.6 \times 10^{7}$ |
| (d) | sq. root of 640,000 | ans. $8.0 \times 10^{2}$ |
| (e) | sq. root of 0.000081 | ans. $9.0 \times 10^{-3}$ |

2. Evaluate the following and express the results in scientific notation.

| | | |
|---|---|---|
| (a) | 1500 X 260. | ans. $3.9 \times 10^{5}$ |
| (b) | 40 / 20,000 | ans. $2 \times 10^{-3}$ |
| (c) | 82,800 / 0.12 | ans. $6.9 \times 10^{5}$ |
| (d) | (1.728 X 17.28 / 0.0001728 | ans. $1.728 \times 10^{5}$ |
| (e) | sq. root of 14,400 times the sq. root of 0.000025 | ans. $6.0 \times 10^{-1}$ |
| (f) | $(1 \times 10^{-3})(2 \times 10^{5})^{2}$ | ans. $4 \times 10^{7}$ |
| (g) | $(3 \times 10^{2})^{3}(2 \times 10^{-5})^{2}$ divided by $3.6 \times 10^{-8}$ | ans. $3 \times 10^{5}$ |
| (h) | 220 X 35,000 | ans. $7.7 \times 10^{6}$ |
| (i) | (16,000)(0.0002)(1.2) divided by (2000)(0.006)(0.00032) | ans. $1 \times 10^{3}$ |
| (j) | (0.004)(32,000)(0.6) divided by (6400)(3000)(0.008) | ans. $5 \times 10^{-5}$ |

## REVIEW EXERCISES FOR TEMPERATURE CONVERSIONS

1. Convert each of the following temperatures to the scale indicated.

| | |
|---|---|
| (a) 67 °F = ________°C | ans. 9.4 |
| (b) -8 °F = ________°F | ans. -22 |
| (c) 355 °C = ________°K | ans. 628 |
| (d) 150 °K = ________°C | ans. -123 |
| (e) 120 °F = ________°K | ans. 322 |
| (f) -50 °F = ________°K | ans. 227 |
| (g) 30 °C = ________°F | ans. 86 |
| (h) -430 °F = ________°C | ans 256.7 |
| (i) 8 °K = ________°F | ans. -445 |
| (j) 760 °K = ________°C | ans. 487 |
| (k) 14 °F = ________°C | ans. -10 |
| (l) 5 °F = ________°C | ans. -15 |
| (m) -20 °C = ________°F | ans. -4 |
| (n) 180 °K = ________°C | ans. -93 |
| (o) 14 °F = ________°K | ans. 263 |

## PREPARATION OF STAINS, SOLUTIONS, AND REAGENTS

Many solutions are given in percentage concentrations. In order to prepare a solution of a given percentage, use the number of grams of material equal to the percentage and add enough solvent to equal 100 mL. For example, a 10% sodium hydroxide solution is prepared by dissolving 10g sodium hydroxide in 90 mL water.

To reduce the concentration of an existing solution, pour the required percentage number of milliliters of the solution into a graduated cylinder. Add enough distilled water to bring the total volume in milliliters to equal the percentage of the original solution. For example, to reduce 95% alcohol to 80%, pour 80 mL of 95% alcohol into a graduated cylinder. Add enough distilled water to bring the volume to 95 mL. You now have 95 mL of 80% alcohol.

Agar, nonnutrient
15 g agar
1000 mL distilled water
Mix and heat until agar dissolves. Stir constantly to avoid burning. To sterilize, autoclave at 15 pounds pressure for 15 minutes.

Agar, nutrient
3 g beef extract
5 g peptones
15 g agar
1000 mL distilled water
Dissolve agar in hot water. Adde peptone and beef extract. Sterilize in container at 15 pounds pressure for 15 minutes.

Ammonium hydroxide solution, dilute
1 part conc. ammonium hydroxide
4 parts water
Add ammonium hydroxide to water

Benedict's solution
173 g sodium citrate
100 g anhydrous sodium carbonate
17.3 g copper sulfate
1000 mL distilled water
Add sodium citrate and sodium carbonate to 600 mL distilled water. Heat until chemicals are dissolved. Filter this solution. Dissolve copper sulfate in 150 mL distilled water. Slowly add copper sulfate solution to the socium citrate/sodium carbonate solution, stirring constantly. Add enough distilled water to bring the whole solution to 1 liter.

Biuret reagent
3 g copper sulfate
12 g potassium sulfate
1 liter of distilled water
600 mL 10% sodium hydroxide (Cautin: very caustic)
Dissolve copper sulfate and potassium tartrate in 1 liter of distilled water. Add 10% sodium hydroxide to the solution with constant stirring.

Brom thymol blue indicator
0.1 g brom thymol blue
1000 mL distilled water
Dissolve the brom thymol blue in the distilled water. If the solution appears green, add 0.4% sodium hydroxide, one drop at a time, until the indicator appears blue.

Broth, nutrient
3 g beef extract
5 g peptone
1000 mL distilled water
Dissolve beef extract and peptone in distilled water. Sterilize in the containers in which it will be used.

Carmine red
1 g carmine red
100 mL distilled water
Dissolve carmine red in distilled water.

Cobalt chloride paper
5 g cobalt chloride
100 mL distilled water
Dissolve cobalt chloride in distilled water. Soak sheets or strips of filter paper in this solution. Allow to dry until blue and store in tightly stoppered bottles. If papers turn pink, restore blue color by heating.

Congo red solution
1 g Congo red
10 mL ethyl alcohol
90 mL distilled water
Add Congo red in alcohol to distilled water.

Crystal (gentian) violet
3 g crystal violet
20 Ml 95% ethyl alcohol
0.8 g ammonium
80 mL distilled water
Add alcoholic crystal violet solution (3 g crystal violet to 20 mL 95% ethyl alcohol) to 1% aqueous ammonium oxalate. (0.8 g ammonium to 80 mL distilled water).

FAA (Formaldehyde, Alcohol, Acetic Acid)
10 mL 40% formaldehyde
50 mL 95% ethyl alcohol
2 mL glacial acetic acid
40 mL distilled water

Fehling's solution
34.6 g coper sulfate
500 mL distilled water
Dissolve copper sulfate in the distilled water

Formalin solution
1 part formaldehyde
19 parts water

Gelatin solution
1 g gelatin
100 mL distilled water
Stir gelatin into cold water, then heat gently.

Gram's iodine
Dissolve 2 g potassium iodide in 100 mL distilled water. Add 1 g iodine crystals. Dissolve slowly.

Hydrochloric acid, 20%
20 parts conc. hydrochloric acid
16 parts water
Carefully pour acid into water. NEVER POUR WATER INTO ACID

Iodine stock solution
5 g iodine crystals
10 g potassium iodide
1000 mL distilled water
Place iodine crystals and potassium iodide into 1 liter flask. Add 100 mL distilled water to dissolve. Add sufficient water to make 1 liter. Refrigerate until needed.

Methylene blue (aqueous alcoholic)
0.3 g methylene blue
30 mL 95% ethyl alcohol
100 mL distilled water
Add 30 mL saturated alcoholic solution methylene blue (0.3 g methylene blue to 30 mL 95% ethyl alcohol) to 100 mL distilled water.

Methyl cellulose solution
10 g methyl cellulose
90 mL water
Dissolve methyl cellulose in water. (Methyl cellulose solution is used to slow down the movement of protozoans).

Nitric acid, dilute
1 part conc. nitric acid
4 parts water
Add acid to water.

Phenylthiocarbamide (PTC) solution
50 mg phenylthiocarbamide (propylthiouracil)
1000 mL distilled water
Dissolve PTC in 100 mL distilled water, then add distilled water to make 1 liter of solution.

Ringer's solution (Amphibian)
0.14 g potassium chloride
6.50 g sodium chloride
0.12 g calcium chloride
0.1 g sodium bicarbonate
1000 mL distilled water
Add the minerals to the distilled water and dissolve thoroughly.

Starch solution (1%)
1 g cornstarch or arrowroot starch
100 mL distilled water
Mix starch with 3 mL distilled water to form a paste. Add 97 mL boiling distilled water and stir. Cook for 2 minutes, stirring constantly. Allow to cool.

Sulfuric acid, dilute
1 part conc. sulfuric acid
5 parts water
Add acid to water. DO NOT POUR THE WATER INTO THE ACID.

Thyroid-wheat mixture
whole wheat flour
5 2-grain thyroid tablets
5 mL distilled water
On an analytical balance, weith an amount of whole wheat flour equal in weight to five 2-grain thyroid tablets. Grind the tablets and the flour together in a mortar. Add 5 mL of distilled water to form a paste. Spread the paste on a clean glass plate. Allow the paste to dry. Then grind the dried mixture and put it in a stoppered, labeled bottle. Refrigerate until needed.

Yeast suspension
1 g peptone
1/2 packet dry yeast
500 mL 5-10% molasses
Combine ingredients and culture for at least 12 hours at 25-30 °C.

The preceeding stains have been adapted from the following source:

Essentials of Histology
by Jack Burke, Richard J. Weymouth, and Hugo R. Seibel
Barrons Ed. Series, Inc. pp. 5-7.

All inquiries about these stains should be addresed to
Barrons's Educational Series, Inc.
113 Crossways Park Drive
Woodbury, New York 11797

# UNIT IV

## JOURNALS AND PERIODICALS

The following publications provide current information on a variety of topics in science. They are highly recommended as references for science research on the secondary level. Most of these publications are available through the school library as well as the local library. Not all of the publications will present articles at the reading level of high school students. It should be the role of the instructor to interpret articles for the students as it becomes necessary.

American Forests

Animal Kingdom

Astronomy

Audubon

Biology Digest

Natural History

Nature

Nature and Science

Omni

Popular Science

BioScience

Canadian Audubon

Current Science and Aviation

Horticulture

International Wildlife

National Geographic

National Wildlife

Psychology Today

Science Digest

Science 80

Science News

Science World

Scientific American

SciQuest

# GOVERNMENT AGENCIES

The following list of government agencies will help students with additional information pertaining to their science research projects. The instructor should provide this information to the students on an as needed basis.

Agriculture Department
Washington, D.C. 20250

Agricultural Research Service
Dept. of Agriculture
Washington, D.C. 20250

Atomic Energy Commission (AEC)
Washington, D.C. 20250

Coastal and Geodetic Survey
Washington, D.C. 20250

Clearinghouse for Federazl Scientific & Technical Information
Springfield, Virginia 22151

Commercial Fisheries Bureau
Department of the Interior
Washington, D.C. 20240

Defense Department
Washington, S.C. 20301

Environmental Science Service Administration
Department of Commerce
Washington, D.C. 20235

Federal Council for Science & Technology
Washington, D.C. 20506

Federal Water Pollution Control Administration
Department of the Interior
Washington, D.C. 20242

Fish & Wildlife Service
Department of the Interior
Washington, D.C. 20240

Food and Drug Administration
Department of Health, Education and Welfare
Washington D.C. 20201

Forest Service
Department of Agriculture
Washington, D.C. 20250

Geological Survey
Department of the Interior
Washington, D.C. 20405

Health, Education and Welfare Department
Washington, D.C. 20201

Interior Department
Washington, D.C. 20240

Land Management Bureau
Department of the Interior
Washington, D.C. 20240

National Aeronautics and Space Administration
John F. Kennedy Space Center
Kennedy Space Center, Florida 02899

National Agricultural Library
Department of Agriculture
Washington, D.C. 20250

National Museum
Smithsonian Institution
Washington, D.C. 20250

National Park Service
Department of the Interior
Washington, D.C. 20240

National Science Foundation
Washington, D.C. 20550

Naval Oceanographic Office
Department of Defense
Washington, D.C. 20390

Naval Research Office
Department of Defense
Washington, D.C. 20390

Naval Research Office
Department of Defense
Washington, D.C. 20390

Outdoor Recreation Bureau
Department of the Interior
Washington, D.C. 20240

Public Health Service
Department of Health, Education and Welfare
Washington, D.C. 20201

Smithsonian Institute
Washington, D.C. 20560

Soil Conservation Service
Department of Agriculture
Washington, D.C. 20250

Sport Fisheries and Wildlife Bureau
Department of the Interior
Washington, D.C. 20240

## STATE AGENCIES

Department of Agriculture and Consumer Services
Tallahassee, Florida 32304

Atlantic States Marine Fisheries Commission
P.O. Box 2784
Tallahassee, Florida 32304

Department of Citrus
1115 East Memorial Boulevard
P.O. Box 148
Lakeland, Florida 33802

Board of Dentistry
4415 Beach Boulevard
Jacksonville, Florida 32207

Governing Board of the Central & Southern Florida Flood
Control District
901 Everina Street
P.O. Box 1671
West Palm Beach, Florida 33402

Department of Health & Rehabilitative Services
IBM Branch Office Building
660 Apalachee Parkway
Tallahassee, Florida 32304

Florida Drug Abuse Program
320 Blount Street
Tallahassee, Florida 32304

Division of Health
P.O. Box 201
Jacksonville, Florida 32201

Division of Mental Health
425 Larson Building
Tallahassee, Florida 32201

Bureau of Alcoholic Rehabilitation
P.O. Box 1147
Avon Park, Florida 33825

Environmental Land Management Study Committee
Holland Building
Tallahassee, Florida 32304

Department of Military Affairs
The Arsenal
St. Augustine, Florida

Department of Natural Resources
Larson Building
Tallahassee, Florida 32304

Division of Game & Fresh Water Fish
Bryan Building
Tallahassee, Florida 32304

Canal Authority of the State of Florida
803 Rosselle Street
Jacksonville, Florida 32201

Governing Board of the Southwest Florida
Water Management District
P.O. Box 457
Brooksville, Florida 33512

Board of Optometry
547 North Monroe Street
Tallahassee, Florida 32301

Board of Pharmacy
252 East 6th Avenue
Tallahassee, Florida 32301

Department of Pollution Control
300 Tallahassee Bank Building
Tallahassee, Florida 32301

Board of Veterinary Medicine
932 Mason Avenue
Daytona Beach, Florida 32017

Tropical Atlantic Biological Laboratory
Bureau of Commercial Fisheries
Virginia Key
Miami, Florida 33149

Wilaka National Fish Hatchery
Wilaka, Florida 32093 tele. 904-467-2374

## SCIENCE AND TECHNOLOGY CENTERS

Alabama Space and Rocket Center
Tranquility Base
Huntsville, AL 35807

American Museum of Atomic Energy: Oak Ridge
P.O. Box 117
Oak Ridge, TN 37830

American Museum of Natural History
Central Park West at 79th Street
New York, NY 10024

Bell Museum of Natural History
University of Minnesota
10 Church Street, S.E.
Minneapolis, MN 55455

Bishop Museum
P.O. Box 6037
1355 Kalihi Street
Honolulu, HI 96818

Bowers Museum
2002 N. Main Street
Santa Ana, CA 92706

Buffalo Museum of Science
Humboldt Park
Buffalo, NY 14211

Buhl Planetarium and Institute of Popular Science
Allegheny Square
Pittsburgh, PA 15212

California Museum of Science and Industry
700 State Drive
Los Angeles, CA 90037

Canadian Audubon Society
46 St. Clair Avenue East
Toronto, Canada

Center of Science and Industry
280 East Broad Street
Columbus, OH 43215

Charlotte Nature Museum
1658 Sterling Road
Charlotte, NC 28209

Children's Museum
3000 N. Meridian Street
Indianapolis, IN 46208

Cincinnati Health and Science Center
231 Bethesda Avenue
Room 6231
College of Medicine
Cincinnati, OH 45267

Cleveland Health Education Museum
8911 Euclid Avenue
Cleveland, OH 41106

Cranbrook Institute of Science
500 Long Pine Road
Bloomfield Hills, MI 48013

Cumberland Museum and Science Center
800 Ridley Avenue
Nashville, TN 37203

Dallas Health and Science Museum
P.O. Box 26407
Fair Park
Dallas, TX 75226

Des Moines Center of Science and Industry
4500 Grand Avenue
Greenwood Park
Des Moines, IA 50312

Detroit Science Center
52 East Forest Avenue
Detroit, MI 48201

Discovery Center
1944 North Winery Avenue
Fresno, CA 93703

Environmental Center, Inc.
950 Trout Brook Drive
West Hartford, CT 06119

Evansville Museum of Arts and Science
411 S.E. Riverside Drive
Evansville, IN 47713

The Experience Center
16642 Algonquin No. 1
Huntington Beach, CA 92650

Exploratorium
3601 Lyon Street
San Francisco, CA 94123

Fernbank Science Center
156 Heaton Park Drive, N.E.
Atlanta, GA 30307

Field Museum of Natural History
Roosevelt Road at Lake Shore Drive
Chicago, IL 60605

Reuben H. Fleet Space Theatre and Science Center
1875 El Prado, Balboa Park
P.O. Box 33303
San Diego, CA 92103

Franklin Institute Science Museum and Planetarium
20th and Parkway
Philadelphia, PA 19103

Hall of Science of the City of New York
Box 1032
Flushing, NY 11352

Don Harrington Discovery Center
1200 Streit Drive
Amarillo, TX 79106

Hillsborough County Museum
1101 E. River Cove
P.O. Box 8311
Tampa, FL 33674

Intermountain Science Center
1776 Science Center Drive
P.O. Box 1802
Idaho Falls, ID 83401

International Museum of Surgical Sciences
1524 N. Lake Shore Drive
Chicago, IL 60610

Kansas City Museum of History and Science
3218 Gladstone Blvd.
Kansas City, MO 64123

Lakeview Museum of Arts and Sciences
1125 West Lake Avenue
Peoria, IL 61614

Lawrence Hall of Science
Centennial Drive
University of California
Berkeley, CA 94720

Maryland Science Center
601 Light Street
Baltimore, MD 21230

Mayo Medical Museum
Mayo Clinic
Rochester, MN 55901

Metropolitan Science Center
The Pavilion
City Park Lake
Denver, CO 80205

Michigan Space Center
2111 Emmons Rd.
Jackson, MI 49203

Milwaukee Public Museum
800 Wells Street
Milwaukee, WI 53233

Museum of Art, Science, and Industry
4450 Park Avenue
Bridgeport, CT 06606

Museum of Medical Science
5800 Caroline Hermann Park
Houston, TX 77004

Museum of Science
Science Park
Boston, MA 02114

Museum of Science
3280 S. Miami Avenue
Miami, FL 33129

Museum of Science and Industry
57th Street and Lake Shore Drive
Chicago, IL 60637

Museum of Science and Natural History
Oak Knoll Park
Sl Louis, MO 63105

National Atomic Museum
P.O. Box 5400
Albuquerque, NM 87115

National Museum of History and Technology
14th St. and Constitution Ave., N.W.,
Washington, DC 20560

National Museum of Science and Technology
1867 St. Laurent Blvd.
Ottawa, Ontario KIA OM8

National Speleological Society
2318 N. Kenmore Street
Arlington, VA 22201

Nature/Science Park
Museum Drive
Winston-Salem, NC 27105

North Carolina Museum of Life and Science
433 Murray Avenue
Durham, NC 27704

North Shore Science Museum
1526 North Plandome Road
Plandome Manor, NY 12308

Oakland Museum
1000 Oak Street
Oakland, CA 94607

Oklahoma Science and Arts Foundation
3000 Pershing Blvd.
Fair Park
Oklahoma City, OK 73107

Ontario Science Center
770 Don Mills Road
Don Mills, Ontario M3C IT3

Oregon Museum of Science and Industry
2015 S.W. Canyon Road
Portland, OR 97221

Pacific Science Center
200 Second Avenue
N. Seattle, WA 98109

Peninsula Nature and Science Center, Inc.
524 J. Clyde Morris Blvd.
Newport News, VA 23601

Rockford Arts and Science Center
401 South Main Street
Rockford, IL 61101

San Antonio Museum of Transportation
3801 Broadway
San Antonio, TX 78209

Santa Barbara Museum of Natural History
2559 Puesta Del Sol Road
Santa Barbara, CA 93105

The Schenectady Museum
Nott Terrace Heights
Schenectady, NY 12308

Science Museum and Planetarium of Palm Beach County
1141 West Lakewood Road
West Palm Beach, FL 33405

Science Museum of Minnesota
30 East 10th Street
St. Paul, MN 55101

Science Museum of Virginia
2500 West Broad Street
Richmond, VA 23220

Space Science Center
De Anza and Foothill Colleges
12345 El Monte Road
Los Altos Hills, CA 94022

St. Louis Medical Museum
3839 Lindell Blve.
Stl Louis, MO 63108

Western Museum of Mining and Industry
1025 Northgate Road
Colorado Springs, CO 80908

NOTE: Other listings are available from

Association of Science-Technology Centers
2100 Pennsylvania Avenue, N.W.
Washington, DC 20037

## MAJOR SCIENCE COMPETITIONS

The following dates are tentative and should only serve as a reminder for the science competitions available to the students.

| | | |
|---|---|---|
| 1. | Westinghouse County Fair | November |
| 2. | School Science Fair | January |
| 3. | County Science Talent Search | February |
| 4. | County Science Fair | February |
| 5. | J.E.T.S. Competition | March |
| 6. | Junior Academy of Science | March |
| 7. | State Science Talent Search | April |
| 8. | State Science Fair | April |
| 9. | Jason Colloquium | April |
| 10. | International Science & Engineering Fair | May |

# GENERALIZED SCIENCE FAIR INFORMATION

All teachers actively involved in science research should be aware of the following information and should use the information as a 'checklist' for preparing students for competition. All items listed may be obtained from the department chairperson.

1. Parental Permission & Insurance Statement
2. Information regarding the Westinghouse Science Talent Search
3. County Science Fair Registration Request Forms and Competition Guidelines
4. County Science Fair Calendar of Events
5. County Science Fair Judging Criteria
6. Applications for the Annual Science Talent Search
7. Information regarding the State Talent Search special awards & scholarships
8. Guidelines on the International Science & Engineering Fair

Each school throughout the state is updated annually on all science related events. Copies of all current information are on file in the department chairperson's office.